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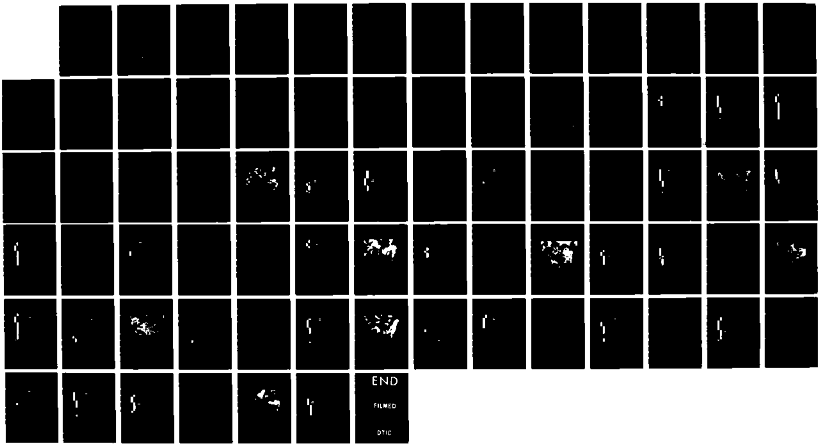

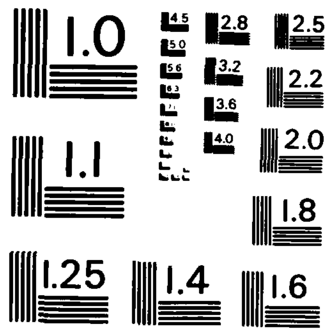

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The Aircraft Icing Environment in Wintertime, Low Ceiling Conditions

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Radiosonde (Raob) temperature and humidity data were used to deduce the vertical distribution of clouds and aircraft icing conditions near Washington, DC when low ceilings ($\leq$1000 ft) (0.3 km) occurred along with surface temperatures near freezing. Twenty three raobs from twelve, cold, low-ceiling episodes during the winter of 1981–1982 were examined for this study. The raobs showed that: a) generally a deep, apparently unbroken cloud layer existed above the low ceilings, b) typically a cold surface layer existed under a relatively strong inversion which raised the air temperature aloft by an average of nearly 7°C, c) the inversion layers typically extended from roughly 1500 ft to 5000 ft (0.5 to 1.5 km) AGL, d) half of the cases also involved an isothermal layer occurring above, below, or instead of the inversion in about equal frequencies. In 15 (65%) of the soundings, the inversion and/or isothermal layer established an elevated "warm" layer ($T \geq 0$°C) averaging about 7000 ft (2 km) deep. In six (25%) cases this "warm" layer was based at the surface; but in nine (40%) of the cases, icing conditions averaging 2800 ft (0.9 km) deep would have to be penetrated to reach the "warm" (icing-free) layer

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aloft. In another 35% of the cases the inversion was insufficient (or occasionally absent) so that temperatures aloft never exceeded 0°C and therefore ascent through 14,000 to 22,000 ft (4 to 7 km) of icing conditions would have been required to reach clear air above the clouds. Thus, while icing conditions above cold, low-ceilings were mitigated to some extent 85% of the time by inversions and/or isothermal layers, 70% of the cases still required flight into significant icing conditions in order to reach an elevated warm layer or to ascend above the cloud system altogether.

Automated predictions of the vertical distribution of icing probability, type, and severity were generated from the Raob data. The technique employs a U.S. Air Force method that has been computerized by one of the authors (RKJ) for use on Hewlett Packard model 9845 computers. The predictions were compared with pilot reports from the vicinity and reasonable agreement was found.

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PREFACE

The collaboration among the authors for this study has been fostered by the recent establishment of the NAVAIR Research Chair in Meteorology at the U. S. Naval Academy (USNA). One of the authors (NBG) was the occupant of the Research Chair during this study and another (RKJ) was the first occupant in 1980-81. Acknowledgement is also due to CDR John Simpson, Chairman of the USNA Oceanography Department during this study, for encouraging this collaborative work between his faculty (NBG), students (MRH and MDM), and outside researchers (RKJ). Another USNA student, Matt Schatzle, also helped on the reduction of the surface observation data.

THE AIRCRAFT ICING ENVIRONMENT IN WINTERTIME, LOW CEILING CONDITIONS

INTRODUCTION

During the past decade there has been a renewed interest in the topic of aircraft icing, particularly among the civilian and military helicopter communities. Helicopter operators are interested in less-restricted cold weather operations and manufacturers want to provide ice-protected aircraft. In order to provide practical guidance and realistic certification requirements, the Federal Aviation Administration (FAA) has been re-examining the icing environment over the 10,000 ft (3km) altitude range above ground level (AGL) where most helicopter flights take place (Masters, 1983).

Recently, a major, new compilation of cloud physics data in a variety of wintertime clouds and weather systems was completed (Jeck, 1983) for use by the FAA as a data base for revision, if necessary, of its design and certification requirements for ice protection equipment on helicopters. This data base has been used to determine the range and frequency of occurrence of icing-related variables, especially of supercooled liquid water content and droplet sizes in wintertime clouds at altitudes up to 10,000 ft (3km) AGL. One important meteorological situation that is not yet well represented in the data base is that of cold, low ceiling conditions. To the authors' knowledge, there are no published studies of aircraft icing conditions in cold, low ceiling conditions either.

Cold, low ceiling conditions are defined to occur when the ceiling (i.e., cloud base of an overcast sky) is lower than about 1000 ft AGL and the surface air temperature is near or below $0^{o}C$. These are situations where, if it were necessary to fly, ground obstacle clearance would require flight into these clouds and, presumably, into icing conditions.

It is known that icing conditions generally worsen with altitude above cloud base until the top of the cloud or about the $-20^{o}C$ level is reached. This is because the liquid water content (LWC) and average droplet size in clouds generally increase with height above cloud base. The supercooled LWC, air temperature, droplet size, and horizontal extent of the clouds are the principal environmental variables governing the formation of ice on aircraft surfaces. At air temperatures of about $-20^{o}C$ or below, most of the cloud droplets have converted from liquid to ice and therefore will no longer stick to the surfaces of a passing aircraft. Many wintertime layer clouds are known to be less than three or four thousand feet (1-1.3km) thick and this finite cloud thickness helps to limit the severity of icing conditions. Exceptions to shallow cloud layers regularly occur in cyclonic storms, however. But if clouds become very deep at subfreezing temperatures, snow usually develops and this reduces the airframe icing hazard by depleting any supercooled liquid (ice forming) droplets in the cloud.

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In order to better understand the icing environment associated with wintertime, low ceiling conditions, we have addressed the following questions:

1. How thick are the clouds above low ceilings?

2. Are these clouds vertically continuous or do they occur in separated layers?

3. If the clouds are in layers, what are the thicknesses of the layers and how much separation isthere between layers?

4. Are these answers different with different types of weather situations?

5. What is the severity and vertical extent of icing conditions above these cold, lowceilings?

This information is of practical importance in forecasting or assessing current icing conditions for helicopter operations. It would also be important for pilots to know if and when the overcast is thin enough for them to climb above it without risking serious icing conditions on the way up.

RESULTS

Twelve occurrences of cold, low ceiling conditions in the Washington, D.C. area were noted by one of the authors (RKJ) during the winter of 1981-1982. Subsequently, weather records for these twelve periods were obtained from the archive files at the National Climatic Data Center* (NCDC) in Asheville, North Carolina. These records included surface analysis maps, synoptic radiosonde (Raob) data from nearby Dulles International Airport (IAD), and hourly surface weather observations from the three local, major commercial airports, IAD, Washington National (DCA), and Balimore-Washington International (BWI). The location of these airports is shown in Fig. 1.

Cloud layers were inferred from the dewpoint depression profiles in the raobs. Aircraft icing conditions (i.e., icing probability, type, and severity) were determined as a function of altitude from the raob data with the technique developed by the USAF Air Weather Service (1980). The USAF icing forecast method is based on research performed in the 1950s, but the method is still considered to be the most advanced currently in use. The fact that the method relies on raobs for input permits good vertical resolution, usually, but is also a drawback in the sense that synoptic raob launches are infrequent (every twelve hours) and are widely spaced. For comparison with the icing conditions determined by the USAF method, actual occurrences of icing were obtained from pilot reports (PIREPS) filed at the time with the National Weather Service Forecast Office in Washington, DC. PIREPS are filed by pilots when they observe weather that they consider to be significant for aircraft operations.

Narrative descriptions of the twelve episodes are given in the Appendix.

VERTICAL DISTRIBUTION OF CLOUDS ABOVE COLD, LOW CEILINGS

The existence of clouds was inferred from the raob data by using the dewpoint depression as an indicator (Aerographer's Mate Training Manual (1974) pp 324-326). The following rules were used to produce the cloud layer information displayed in Table 1.

1. A cloud base is indicated at the base of a sharply decreasing dewpoint depression.

2. The dewpoint depression (as determined from the raob sensors) in a cloud is typically 1° to $2^{\circ}C$ at temperatures of $0^{\circ}C$ and above, and ranges to $4^{\circ}C$ between -10° and $-20^{\circ}C$.

3. The top of a cloud layer is usually indicated by a significant increase in dewpoint depression. In the average raob sounding through a cloud, the gradual increase of dewpoint depression with height is not significant.

*NCDC is a part of the National Oceanographic and Atmospheric Administration (NOAA).

From Table 1 it is seen that in 90% of the soundings, only one, apparently continuous cloud layer was found in the 0-10,000 ft (3km) AGL interval. More than half of these were deep clouds extending from the low ceiling to well above 10,000 ft (3km) AGL. In only three cases were the cloud layers less than 6000 ft (2km) thick. This means that deep, continuous cloud systems are generally present above cold, low ceilings and there is, therefore, seldom any chance for helicopters to escape the clouds by climbing above them.

EFFECTS OF LOCAL TOPOGRAPHY ON HEIGHT OF COLD, LOW CEILINGS

Local topography has a pronounced effect on the height of low ceilings and visibilities at Washington National Airport (DCA). Hourly surface observations show that in the episodes studied for this report, ceilings dropped by about 100-300 ft (30-100m) and visibilities decreased to less than one mile (1.6km) when the surface wind direction at DCA was near 50°. This direction coincides with the orientation of the Anacostia River whose confluence with the Potomac River occurs near DCA (see Fig. 2). The increased fetch over the Anacostia River when the surface winds are from 50° advects more moisture over the airport than winds from other directions. Therefore, ceilings at DCA can lower significantly when the wind blows from this critical direction. Prior to this study, we had not expected that the localized moisture source would have such a noticeable effect on the weather at this airport.

Moisture sources near the Baltimore Washington International Airport are also important controls of the airport's weather. The Chesapeake Bay lies to the east and the Patapsco River lies to the northeast of the airport (see Fig. 3). The airport, however, is about 7 miles away from the water so that the effects of the moisture are less than at Washington National Airport, which is adjacent to the Potomac River. A wind blowing from a broad northeasterly directional band is sufficient to lower ceilings and visibilities at BWI. This result contrasts the importance of wind from a narrow directional band at DCA.

Correlation between wind direction and low ceilings and visibilities at Dulles International Airport is weak. Lack of a nearby water source (see Fig. 1) precludes localized moisture advection. The mesoscale and synoptic conditions are therefore more important than the local topography.

VERTICAL PROFILES OF ICING CONDITIONS

Atmospheric conditions between the surface and 10,000 ft (3km), as revealed by 23 radiosonde launches at IAD, showed a consistent pattern of strong inversions above a cold surface layer, and a generally deep, and apparently unbroken cloud layer above the low ceilings. An analysis of the data presented in Table 2 shows that about 80% of the inversions raised the temperature by 5°C or more over an average inversion layer depth of about 2900 ft. Half of the soundings contained additional isothermal layers either above or below the inversion or, in three cases, instead of an inversion.

Averaged over all cases, the inversions and/or isothermal layers kept the air temperature above $0^{o}C$ for an average of about 4700 ft in the altitude interval 0-10,000 ft (3km) AGL. There were eight soundings in which the temperature aloft never rose above $0^{o}C$.

These inversions and/or isothermal layers have the important effect of substantially reducing the icing hazard above cold, low ceilings. While the near surfaces are cold and moist and favorable for aircraft icing, much of the airspace up to 10,000 ft can be warmer than freezing and therefore not conducive to airframe icing. Instrument flight rules (IFR) generally apply below 10,000 ft, but the frequent existence of a warm layer increases the opportunity for uneventful flights into these cold, low ceiling conditions. In six (25%) of the 23 soundings studied, the clouds were warm up to at least 5000 ft (1.5 km) AGL so that low level icing was not a hazard. A representative sounding for this situation is given in Fig. 4. Nevertheless, about 70% of the cases would still involve <u>some</u> exposure to icing conditions. In nine (40%) of the cases a low icing layer would have to be penetrated in order to reach the warmer, ice-free layer aloft. These low icing layers ranged from 500 to 5200 ft (1.6 km) thick---the average thickness being about 2800 ft (0.9 km). A representative case is shown in Fig. 5. These low icing layers necessarily occur in the low levels of the clouds, too, so that the icing intensity, while not necessarily negligible, will be minimized. In eight (35%) of the cases, icing would have been present for any practical flight plan. Three of these eight cases were the ones where the temperature was below $0^{o}C$ at all altitudes, an example of which is shown in Fig. 6. In the other five cases, the warm layers were all below 2000 ft (0.6 km) so that any flight path above 2000 ft would involve at least minimum icing intensities in the lower levels of the clouds again.

In some cases, however, carburetor or engine inlet icing may still be a concern whenever the outside air temperature is less than about $+5^{o}C$ during flight in the clouds. This icing hazard results if reduced air pressures in the inlet system cause the moist air to cool below $0^{o}C$ during ingestion.

COMPUTATION OF ICING CONDITIONS FROM RAOB DATA

Mansur (1984) and Tucker (1983) present an excellent review of the current procedures for forecasting icing. They describe the generalities and assumptions implicit in the various methods. Significant problems include a lack of a meteorological definition of icing intensity, the absence of LWC data (needed to describe icing intensities) among the routinely observed meteorological variables, the effects of precipitation on icing, and the localized effects that are not evident on a synoptic scale. These problems lead to very general forecasts that tend to err on the conservative side, i.e., a real extent and intensities are usually forecast to be greater than observed.

The icing assessment method we have used in this study is the detailed "overlay" procedure described in the USAF AWS manual (1980) and by Tucker (1983). This method produces a vertical profile estimate of the icing type (rime, clear, mixed) and intensity (trace, light, moderate, severe) in the

airspace represented by the raob sounding used for input data. The type of icing is determined from the temperature lapse rate between sounding levels in cloud layers above the freezing level. Stable layers (lapse rate less than the saturated (wet) adiabatic lapse rate) are assumed to represent stratiform clouds and rime icing. Conditionally unstable layers (lapse rate intermediate between the wet and dry adiabatic rates) represent cumuliform clouds and clear icing. The theoretical lapse rates vary somewhat with temperature and altitude, but for temperatures between 0^o and -20^oC in the altitude range 0-10,000 ft (0-3km or 1000-700mb), the theoretical, dry adiabatic lapse rate is about $5.5^oF/1000$ ft ($1^oC/100m$) and the wet adiabatic lapse rate is about $3.3^oF/1000$ ft ($0.65^oC/100m$). Icing type also has a coarse dependence on the air temperature in the cloud. For cumuliform clouds (unstable and conditionally unstable layers), clear icing is expected at temperatures between 0^o and -8^oC, while mixed (rime and clear) icing is expected for temperatures between -8^oC and -15^oC. For temperatures below -15^oC only rime icing is anticipated, irrespective of the stability.

Once the type of icing has been determined for altitude intervals along the sounding, the Skew T, log P graph of the sounding is used along with a transparent overlay to determine the expected severity of the icing with altitude. Figure 7 shows a reduced version of the overlay. The curves delimiting the various thresholds of icing severity are based on expected values of supercooled liquid water content as a function of temperature and height above cloud base.

Combined Skew T, log P and icing intensity plots are given in the Appendix for each of the soundings used in this study. The graphs shown are products from a computerized version of the AWS overlay technique. The computerized version was recently developed by one of the authors (RKJ) for use by Navy forecasters.

It is important to remember that radiosonde observations give a description of the atmosphere above a single geographic location and do not necessarily represent the conditions at nearby locations. In this study, for example, the raobs at IAD do not always represent the exact conditions above DCA or BWI.

COMPARISON OF FORECASTED ICING CONDITIONS WITH PILOT REPORTS

Icing forecasts for 14 events, based on IAD radiosonde observations, were verified by pilot reports of icing. Results show that for two cases icing was neither forecast nor observed, and that for four cases icing was both forecast and observed. In three cases it was forecast but was not reported, and in two cases it was not forecast but did occur. These results were better than expected considering the problems with icing forecasting and verification.

Icing forecast verification via pilot reports is hampered by three deficiencies. First, reports are a function of the number of aircraft flying through an area at any given time, place and altitude. Icing will not be reported, even though it may be occurring, if no aircraft fly through the

area. Second, reports are made at the discretion of the pilot. The reports are made subject to the pilot's interpretation of the atmospheric conditions and his experience. Third, reported intensities are also dependent on the effects of the icing on an individual aircraft type so that reports are not always indicative of the existing meteorological conditions. The result of these defects in the verification procedure is that icing probably occurs more often and over wider areas than is reported.

SUMMARY

This study shows that common features exist in distinct episodes of cold, low ceilings, and that icing conditions are frequently and significantly mitigated by presence of an inversion and/or isothermal layer. Raob data indicate that deep, apparently continuous cloud systems are generally present above cold, low ceilings and, therefore, there is seldom any chance for helicopters to escape the clouds by climbing above them. About 80% of the low ceilings are associated with strong inversion layers above a cold surface layer. In this study the average temperature increase was nearly 7°C over an average inversion layer depth of about 3000 ft (1 km). Half of the cases involved an additional, isothermal layer above, below, or in a few cases, instead of an inversion. Averaged over all the cases studied here, the inversions and/or isothermal layers kept the air temperature above 0°C for an average of 4400 ft (1.4 km) in the altitude range 0-10,000 ft (3 km) AGL. While the inversions and/or isothermal layers have the important effect of substantially reducing the aircraft icing hazard when they bring warmer than freezing temperatures above cold, low ceilings, 70% of the cases would still involve some exposure to icing conditions. In about 40% of the cases a low level icing layer averaging 2800 ft (0.9 km) thick would have to be penetrated to reach the warmer, ice-free layer aloft. Cold temperatures in the lower levels of the overcast would also be unavoidable in the 20% of the cases where the inversions (and their warming effect) were absent. In another 15% of the cases the inversions were not strong enough to bring the air temperature above 0°C at any flight level. The icing intensities in the lower levels of cold clouds, while not necessarily negligible, will generally be minimized because of the small values of liquid water content and droplet size there.

In the Washington, DC area low cloud heights and visibilities are controlled by two features---the synoptic/mesoscale environment and local topography. Approaching frontal systems and low pressure areas near Washington, DC provide the necessary convergence and moisture to generate extensive cloud covers. Low pressure areas and troughs located over the Ohio Valley, Tennessee Valley or in the Southeast influence the Washington area even though these systems are several hundred miles away. Mesoscale high and low pressure areas meandering along a frontal system also have a dominant effect on the local weather. These results were expected and are consistent with the climatology of the region.

Table 1 — Cloud layers and icing intervals above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Cloud Layers Below 3km	Cloud Layer Depth (ft & km)	Cloud Base Temperature (°C)	Icing Interval (ft & km)	Weather Situation Responsible for Low Ceiling Conditions
(1981)						
Nov 24	1100	1	1800–25,000 ft 0.6–7.6 km	0	1900–18,000 ft 0.6–5.6 km	Low pressure center and occluded front 250 nmi (500 km) to the west.
Nov 24	2300	1	300–18,000 ft 0.1–5.5 km	+1	600–18,000 ft 0.2–5.5 km	Low pressure center moving through the local area.
Dec 1	2300	1	300–12,500 ft 0.1–3.8 km	+2	11,000–12,500 ft 3.4–3.8 km	Low pressure center and occluded front nearby to the West
Dec 14	2300	1	300–28,500 ft 0.1–8.7 km	0	300–2600 ft 0.1–0.8 km 7000–23,000 ft 2.1–7.0 km	Warm front 100–200 nmi (200–400 km) to the south and east.
Dec 15	1100	2	300–6500 ft 0.1–2.0 km and 9000–28,000 ft 2.7–8.6 km	+1	--- 9000–23,000 ft 2.7–7.0 km	Cold front 100 nmi east and connecting frontal waves 300–400 nmi to north-east and southwest.
Dec 15	2300	1	400–22,500 ft 0.1–6.8 km	0	500–22,500 ft .15–6.8 km	
Dec 22	2300	2	300–1800 ft 0.1–0.5 km and 7900–14,400 ft 2.4–4.4 km	+3 +4	--- 10,100–14,400 ft 3.1–4.4 km	
(1982)						
Jan 3	2300	1	300–7600 ft 0.1–2.3 km	+1	None	Trough 100 nmi east, frontal wave 200 nmi south.

Table 1 (Cont'd) — Cloud layers and icing intervals above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Cloud Layers Below 3km	Cloud Layer Depth (ft & km)	Cloud Base Temperature (°C)	Icing Interval (ft & km)	Weather Situation Responsible for Low Ceiling Conditions
(1982)						
Jan 4	1140	1	250-29,500 ft 0.1-9.0 km	+1.5	11,000-25,000 ft 3.4-7.6 km	Deep, closed low 700 nmi northwest, complex warm front in local area.
Jan 13	1100	1	500-16,000 ft 0.2-4.9 km	-6	500-16,000 ft 0.2-4.9 km	Weak, low pressure center and widespread snowstorm moving in from south.
Jan 13	2300	1	300-16,000 ft 0.1-4.9 km	-5	300-16,000 ft 0.1-4.9 km	Snowstorm moving out of local area.
Jan 21	1100	1	300-29,500 ft 0.1-9.0 km	-1.7	300-5500 ft 0.1-1.7 km and 6500-24,000 ft 2.0-7.3 km	Trough and weak low 200-300 nmi west, weak lows 300-400 nmi south and southwest.
Jan 21	2300	1	800-7300 ft 0.3-2.2 km	-5	800-7300 ft 0.3-2.2 km	Trough 100-200 nmi west.
Jan 22	1100	1	1500-4500 ft 0.5-1.4 km	-9	1500-4500 ft 0.5-1.4 km	High pressure ridge overhead, winds from northeast off the ocean.
Feb 2	2300	1	500-30,500 ft 0.15-9.3 km	-0.5	500-2300 ft 0.15-0.7 km and 10,000-25,000 ft 3.0-7.5 km	High pressure ridge receding to northeast, warm front approaching from southeast, weak, winds off the ocean.
Feb 3	1100	1	300-7000 ft 0.1-2.2 km and 9500-14,000 ft 2.9-4.2 km	+0.5	500-1400 ft 0.15-0.4 km and 11,500-13,800 ft 3.5-4.2 km	Weak frontal wave overhead, trough 300-400 nmi west.

Table 1 (Cont'd) — Cloud layers and icing intervals above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Cloud Layers Below 3km	Cloud Layer Depth (ft & km)	Cloud Base Temperature (°C)	Icing Interval (ft & km)	Weather Situation Responsible for Low Ceiling Conditions
(1982)						
Feb 3	2300	1	250–5000 ft 0.1–1.5 km	+3.5	14,000–25,000 ft 4.4–7.6 km	Mesoscale frontal waves in the local area.
Feb 9	1100	1	300–28,000 ft 0.1–8.6 km	+0.5	2000–3000 ft 0.6–0.9 km and 9000–24,000 ft 2.7–7.3 km	Warm front 100 nmi south, trough 100 nmi west, frontal wave 200 nmi southwest.
Feb 17	2300	1	300–26,500 ft 0.1–8.1 km	-1	300–4600 ft 0.1–1.4 km and 6200–23,000 ft 1.9–7.0 km	Frontal waves and weak lows 200–300 nmi south, trough 200 nmi west.
Mar 6	2300	1	1650–6800 ft 0.5–2.1 km	-2	1650–2150 ft 0.5–0.65 km	Frontal wave 200 nmi southeast, weak winds off the ocean.
Mar 7	1100	1	300–27,500 ft 0.1–8.4 km	0	300–2400 ft 0.1–0.7 km and 9500–23,000 ft 2.9–7.0 km	Low pressure trough over the local area.
Mar 7	2300	1	300–18,000 ft 0.1–5.5 km	+1.5	1000–23,000 ft 0.3–7.0 km	Low pressure trough.
Apr 9	1100	1	300–15,700 ft 0.1–4.8 km	+0.5	1300–15,700 ft 0.4–4.8 km	

Table 2 — Inversion layers and isothermal layers above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Inversions: Base Height (ft & km)	Inversions: Top Height (ft & km)	Inversions: Layer Thickness (ft & km)	Inversions: Top Temperature (°C)	Inversions: Temperature Increase (°C)	Isothermal Layer: Base Height (ft & km)	Isothermal Layer: Top Height (ft & km)	Isothermal Layer: Layer Thickness (ft & km)	Isothermal Layer: Layer Temperature (°C)	Isothermal Layer: Position Relative to Inversion
1981											
Nov 24	1100	400 ft 0.1 km	900 ft 0.3 km	500 ft 0.15 km	0	1.5			None		
Nov 24	2300			None					None		
Dec 1	2300	1750 ft .55 km	4600 ft 1.4 km	2850 ft 0.9 km	+11	9.5	300 ft 0.1 km	1750ft 0.55 km	1450 ft .45 km	+1.5	Below
Dec 14	2300	2600 ft 0.8 km	4750 ft 1.5 km	2150 ft .65 km	+5	6.5	300 ft 0.1 km	2600 ft 0.8 km	2300 ft 0.7 km	-0.7	Below
Dec 15	1100	1000 ft 0.3 km	2600 ft 0.8 km	1600 ft 0.5 km	+3	2.5	2600 ft 0.8 km	4650 ft 1.4 km	2050 ft 0.6 km	+2.5	Above
Dec 15	2300			None			1500 ft .45 km	8450 ft 2.5 km	6950 ft 2 km	-2	---
Dec 22	2300	1600 ft 0.5 km	1800 ft 0.55 km	200 ft 0.05 km	+10	6.5	300 ft 0.1 km	1600 ft 0.5 km	1300 ft 0.4 km and	+3	Below
							1800 ft 0.55 km	3300 ft 1.0 km	1500 ft 0.45 km	+9.5	Above
1982											
Jan 3	2300	1350 ft 0.4 km	8300 ft 2.5 km	6950 ft 2.1 km	+5	4	300 ft 0.1 km	1350 ft 0.4 km	1050 ft 0.3 km	+1.2	Below

Table 2 (Cont'd) — Inversion layers and isothermal layers above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Inversions Base Height (ft & km)	Top Height (ft & km)	Layer Thickness (ft & km)	Top Temperature (°C)	Temperature Increase (°C)	Isothermal Layer Base Height (ft & km)	Top Height (ft & km)	Layer Thickness (ft & km)	Layer Temperature (°C)	Position Relative to Inversion
1982											
Jan 4	1140	800 ft 0.25 km	5600 ft 1.7 km	4800 ft 1.5 km	+11.5	+10.5			None		
Jan 13	1100	3200 ft 1.0 km	4250 ft 1.3 km	1050 ft 0.3 km	-8	4.5	4250 ft 1.3 km	5750 ft 1.75 km	1500 ft .5 km	-8	Above
Jan 13	2300	1650 ft 0.5 km	3050 ft 0.9 km	1400 ft 0.4 km	-1	5.5			None		
Jan 21	1100	1800 ft 0.55 km	4400 ft 1.35 km	2600 ft 1.1 km	+0.5	5.5			None		
Jan 21	2300	2050 ft 0.6 km	4900 ft 1.5 km	2850 ft 0.9 km	-0.5	6.5	5750 ft 1.75 km	8200 ft 2.5 km	2450 ft 0.75 km	-3.2	Above
Jan 22	1100	2100 ft 0.65 km	6150 ft 1.9 km	4050 ft 1.25 km	+0.5	10			None		
Feb 2	2300	1700 ft 0.5 km	5100 ft 1.5 km	3400 ft 1.0 km	+5	7.5			None		
Feb 3	1100	1350 ft 0.4 km	4900 ft 1.5 km	3550 ft 1.1 km	+12	12.5			None		
Feb 3	2300	300 ft 0.1 km	3300 ft 1.0 km	3000 ft 0.9 km	+10	6.5	6400 ft 2.0 km	10,000 ft 3.0 km	3600 ft 1.0 km	+5.5	Above
Feb 9	1100	2750 ft 0.8 km	5950 ft 1.8 km	3200 ft 1.0 km	+4.5	5			None		
Feb 17	2300	3850 ft 1.2 km	5550 ft 1.7 km	1700 ft 0.5 km	+0.3	6.5			None		

Table 2 (Cont'd) — Inversion layers and isothermal layers above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Inversions: Base Height (ft & km)	Inversions: Top Height (ft & km)	Inversions: Layer Thickness (ft & km)	Inversions: Top Temperature (°C)	Inversions: Temperature Increase (°C)	Isothermal Layer: Base Height (ft & km)	Isothermal Layer: Top Height (ft & km)	Isothermal Layer: Layer Thickness (ft & km)	Isothermal Layer: Layer Temperature (°C)	Isothermal Layer: Position Relative to Inversion
1982											
Mar 6	2300	1850 ft 0.55 km	4650 ft 1.4 km	2800 ft 0.85 km	+6.5	9			None		
Mar 7	1100	1100 ft 0.35 km	4050 ft 1.2 km	2950 ft 0.9 km	+6.9	8			None		
Mar 7	2300			None			4000 ft 1.2 km	9950 ft 3.0 km	5950 ft 1.8 km	+4.3	---
Apr 9	1100			None			300 ft 0.1 km	1200 ft 0.35 km	900 ft 0.25 km and	+0.4	---
							4400 ft 1.35 km	7550 ft 2.3 km	3150 ft 0.95 km	-3.5	---

Table 3 — Temperature profiles above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Surface Temperature (°C)	Minimum Temperature Below 3km (°C)	Maximum Temperature Aloft (°C)	Height of Maximum Temperature (ft and km)	Altitude Interval With T≥0°C (ft and km)
1981						
Nov 24	1100	-1.5	-8	0	900-1800 ft 0.3-0.6 km	900-1900 ft 0.3-0.6 km
Nov 24	2300	+1	-11	+1	Surface	0-600 ft 0-0.2 km
Dec 1	2300	+2	+1.5	+11	3600-5000 ft 1.1-1.5 km	0-11,000 ft 0-3.4 km
Dec 14	2300	-0.5	-1.5	+5	4600 ft 1.4 km	3000-7000 ft 0.9-2.1 km
Dec 15	1100	+1	-4	+3	4300 ft 1.3 km	0-7500 ft 0-2.3 km
Dec 15	2300	0	-4	0	Surface	0-500 ft 0-.15 km
Dec 22	2300	+3	+1	+10	2000-3000 ft 0.6-0.9 km	0-10,000 ft 0-3 km
1982						
Jan 3	2300	+1	+1	+5	5000-8000 ft 1.5-2.5 km	0-13,000 ft 0-4.0 km
Jan 4	1140	+1.5	+1	+11	2500-5000 ft 0.7-1.5 km	0-11,000 ft 0-3.4 km
Jan 13	1100	-5.5	-12.5	-5.5	Surface	None
Jan 13	2300	-4.5	-6.5	-1	2500-3300 ft 0.8-1.0 km	None
Jan 21	1100	-1.5	-5	+0.4	6000 ft 1.8 km	5500-6500 ft 1.7-2.0 km
Jan 21	2300	-3.5	-7	-0.7	4000-5000 ft 1.3-1.5 km	None

Table 3 (Cont'd) — Temperature profiles above cold, low ceilings at Dulles International Airport (Washington, DC)

Date	Raob Release Time (GMT)	Surface Temperature (°C)	Minimum Temperature Below 3km (°C)	Maximum Temperature Aloft (°C)	Height of Maximum Temperature (ft and km)	Altitude Interval With T≥0°C (ft and km)
<u>1982</u>						
Jan 22	1100	-4	-9.5	+0.4	5000-6000 ft 1.6-1.9 km	5000-6000 ft 1.6-1.9 km
Feb 2	2300	0	-2.5	+5	4700-5500 ft 1.4-1.7 km	2300-10,000 ft 0.7-3 km
Feb 3	1100	+0.5	-0.5	+12	4000-5200 ft 1.2-1.6 km	1500-10,000 ft 0.4-3 km
Feb 3	2300	+3.5	+3.5	+10	2000-3600 ft .65-1.1 km	0-11,500 ft 0-3.5 km
Feb 9	1100	+0.5	-1.3	+4.5	6000 ft 1.8 km	0-2000 ft 0-0.6 km and 3000-9000 ft 0.9-2.7 km
Feb 1.	2300	-1	-6.2	+0.5	4900-5500 ft 1.5-1.7 km	4600-6200 ft 1.4-1.9 km
Mar 6	2300	+1.3	-2.4	+6.5	4300-4650 ft 1.3-1.4 km	2300-9500 ft 0.7-2.9 km
Mar 7	1100	0	-1.5	7	3200-4000 ft 1.0-1.2 km	2400-9100 ft 0.7-2.8 km
Mar 7	2300	+1.5	-5.3	+1.5	Surface	0-1000 ft 0-0.3 km
Apr 9	1100	+0.5	-6	+0.5	Surface	0-1300 ft

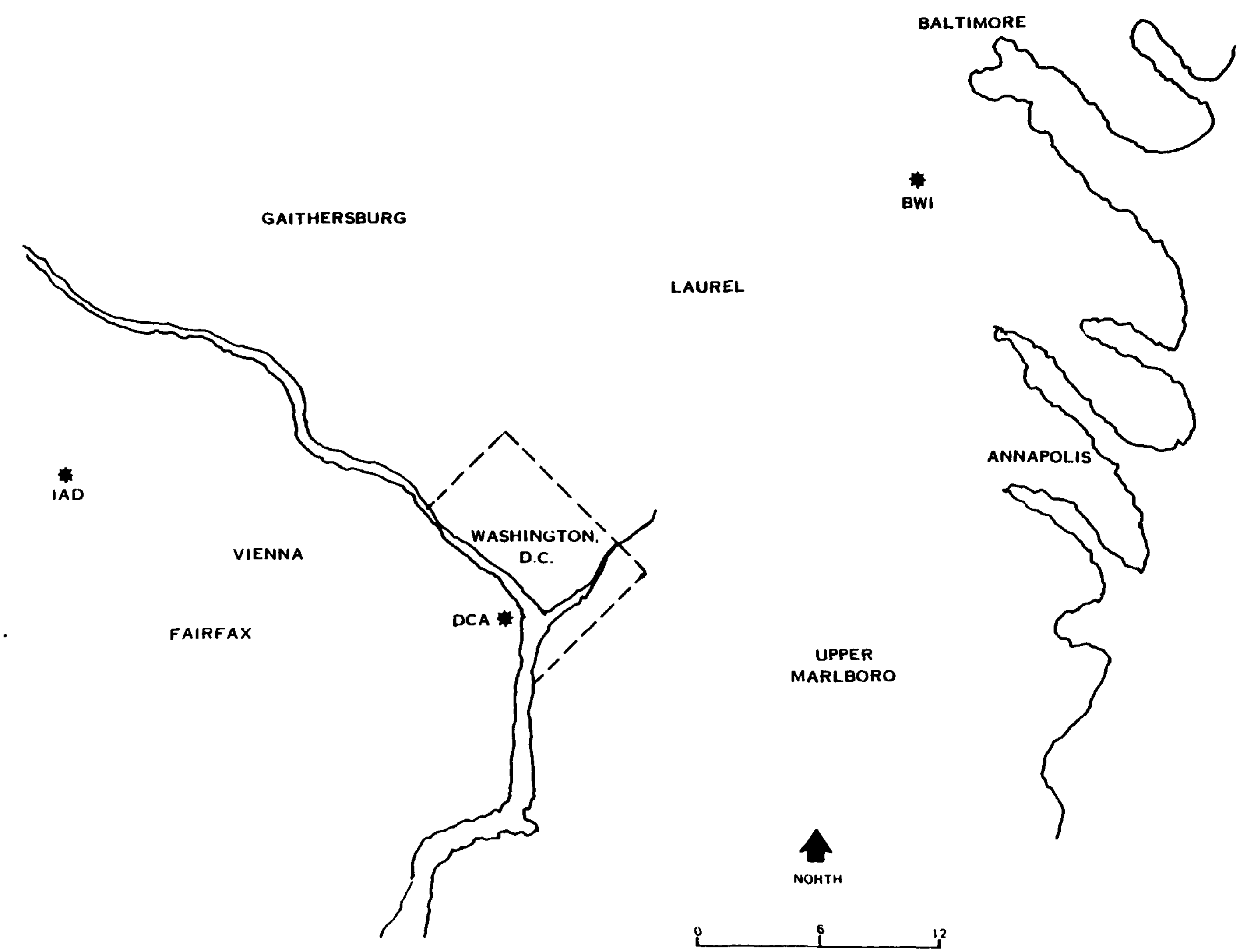

Fig. 1. Location of the three airports IAD, DCA, and BWI from which weather observations were used for this study.

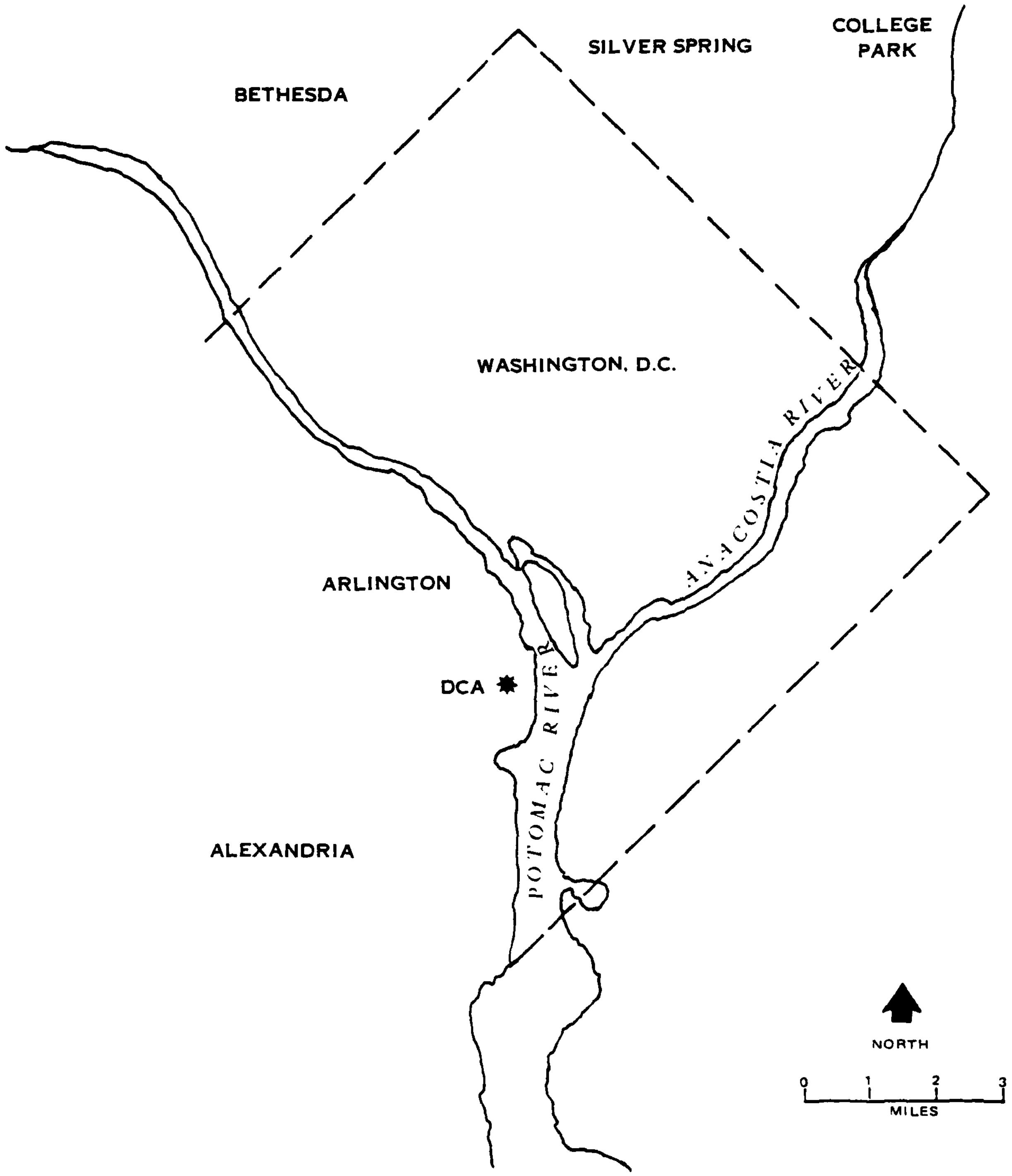

Fig. 2. Location of Washington National Airport (DCA).

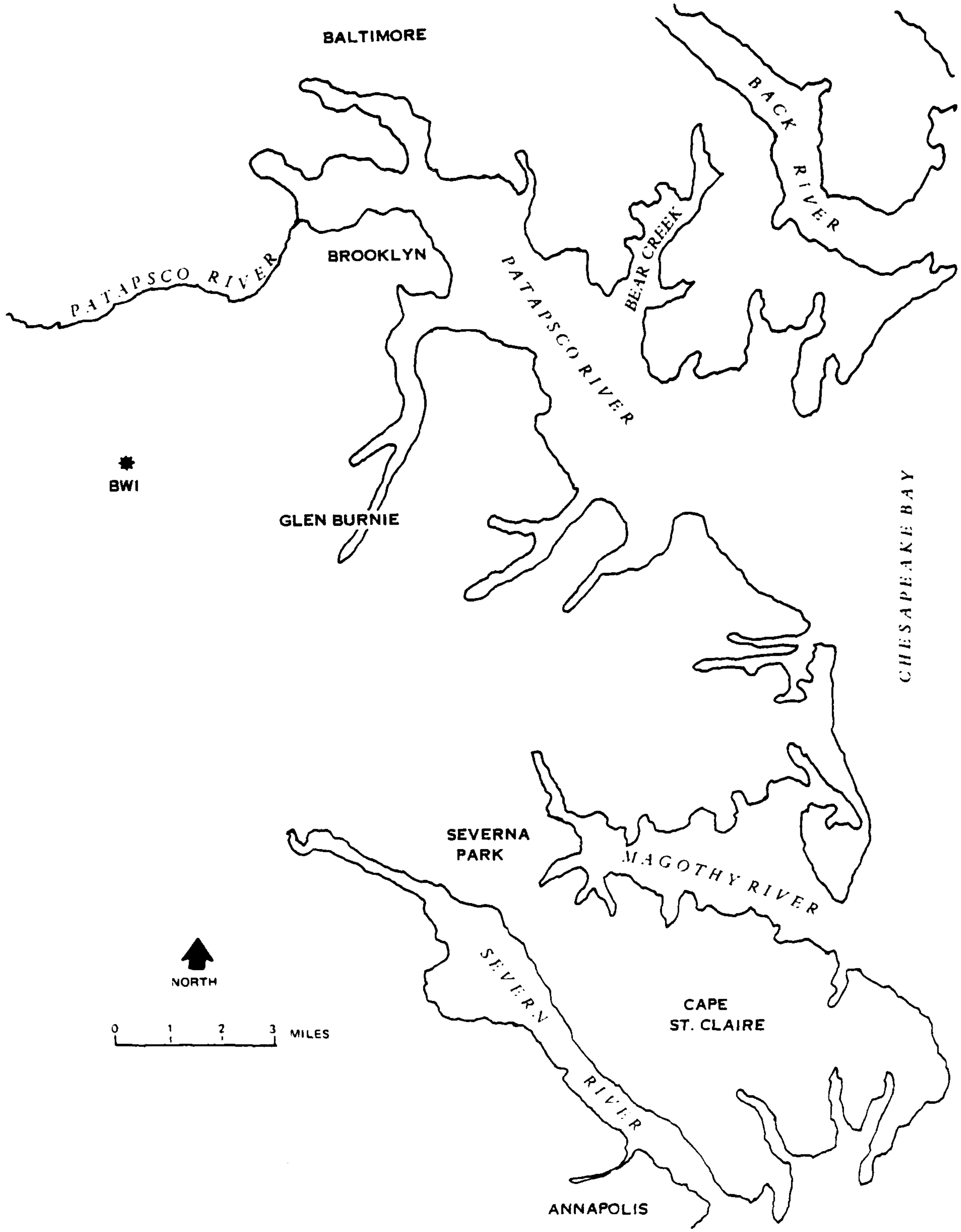

Fig. 3. Location of Baltimore-Washington International Airport (BWI).

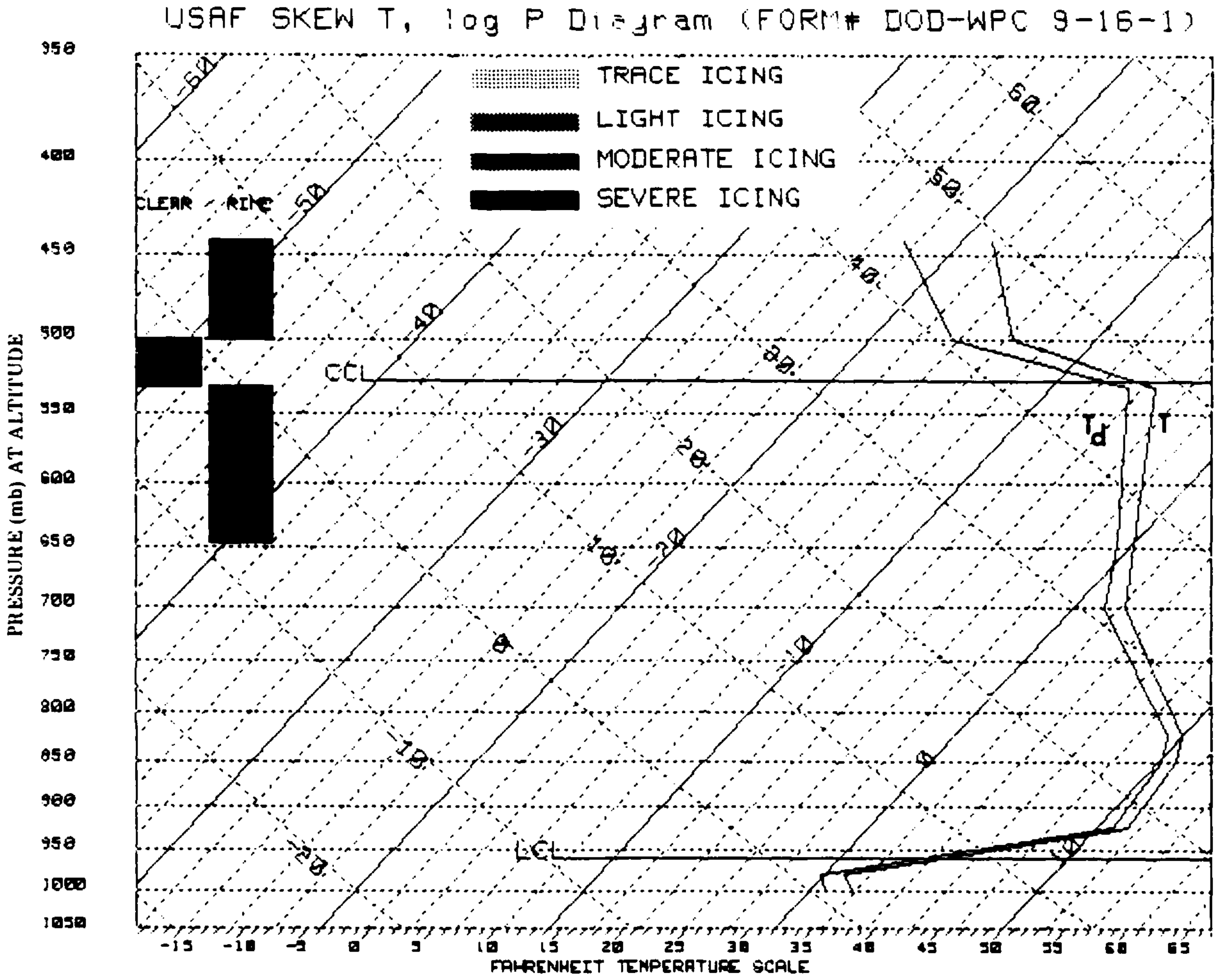

Fig. 4. Representative sounding for 25% of the cases where an inversion, and sometimes an additional isothermal layer, maintains the air temperature (right hand curve) above $0^{o}C$ from the base of the low ceiling up through a large portion of the cloud layer. This particular sounding is from IAD at 1200 GMT on Jan. 4, 1982.

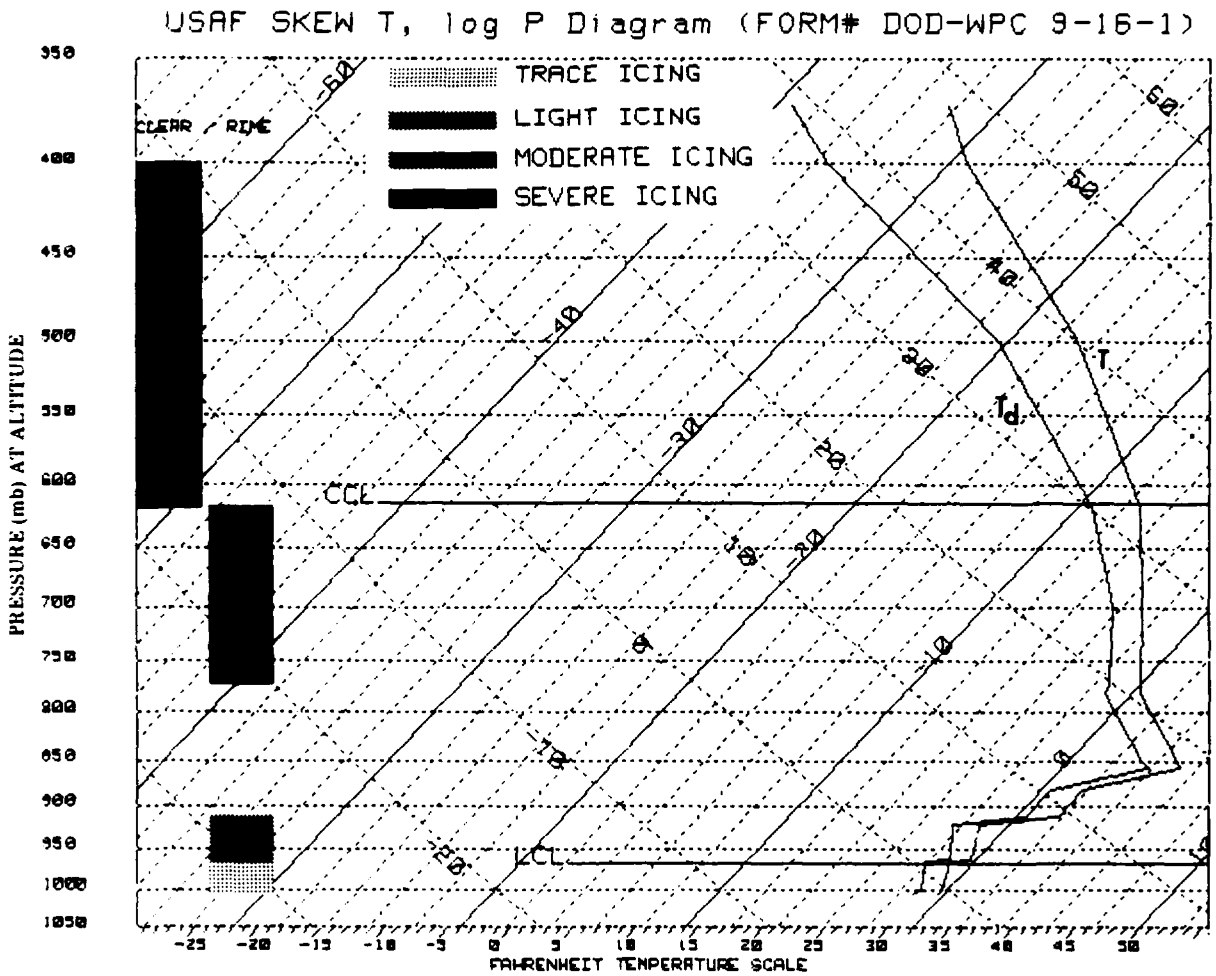

Fig. 5. Representative sounding for 40% of the cases where a low level icing layer must be penetrated in order to reach a warm layer aloft. This particular sounding is from IAD at 2300 GMT on Dec. 14, 1981.

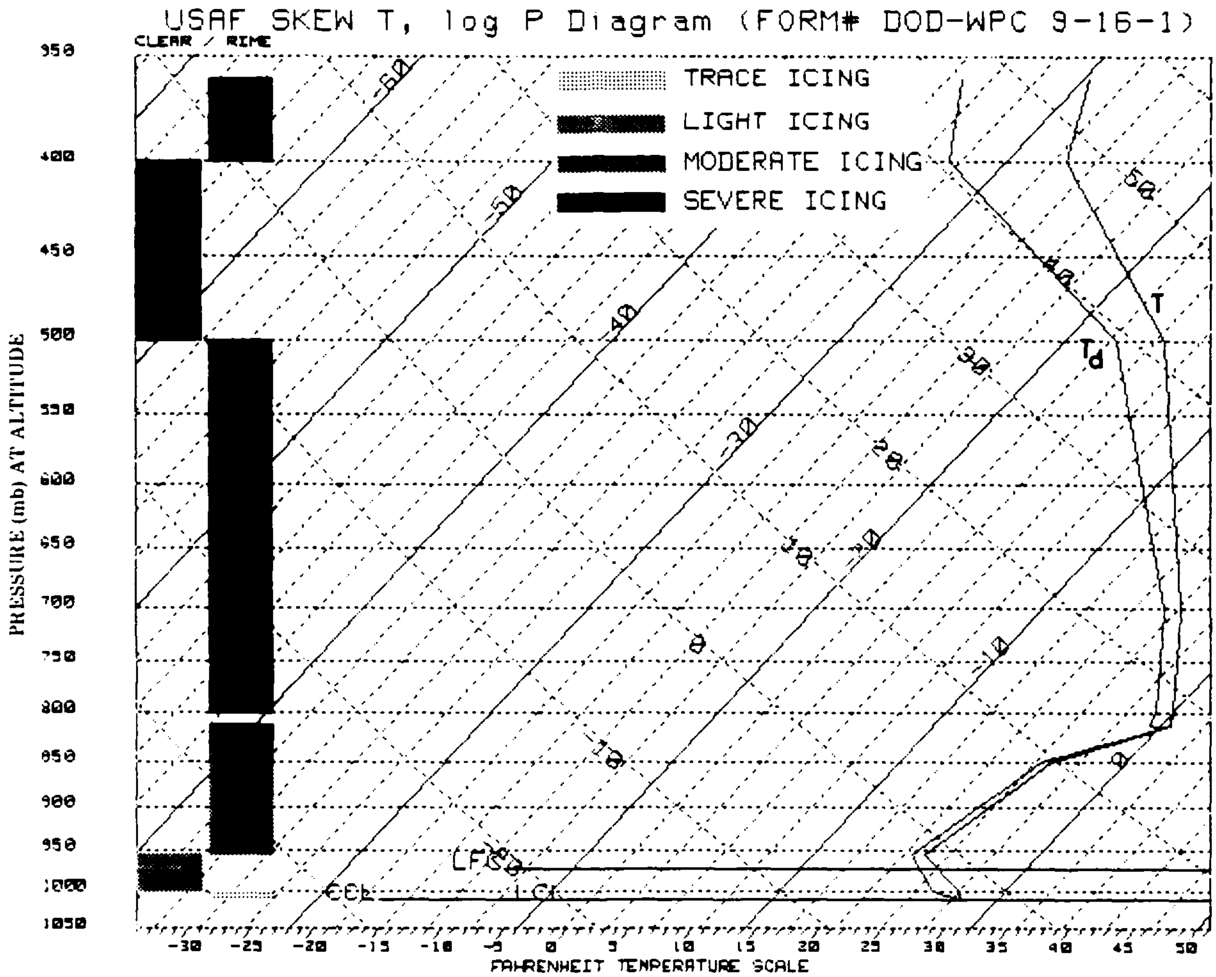

Fig. 6. Representative sounding for the cases where the inversion is insufficient to bring the air temperature (right hand curve) above 0°C. This particular sounding is from IAD at 1200 GMT on Jan. 21, 1982.

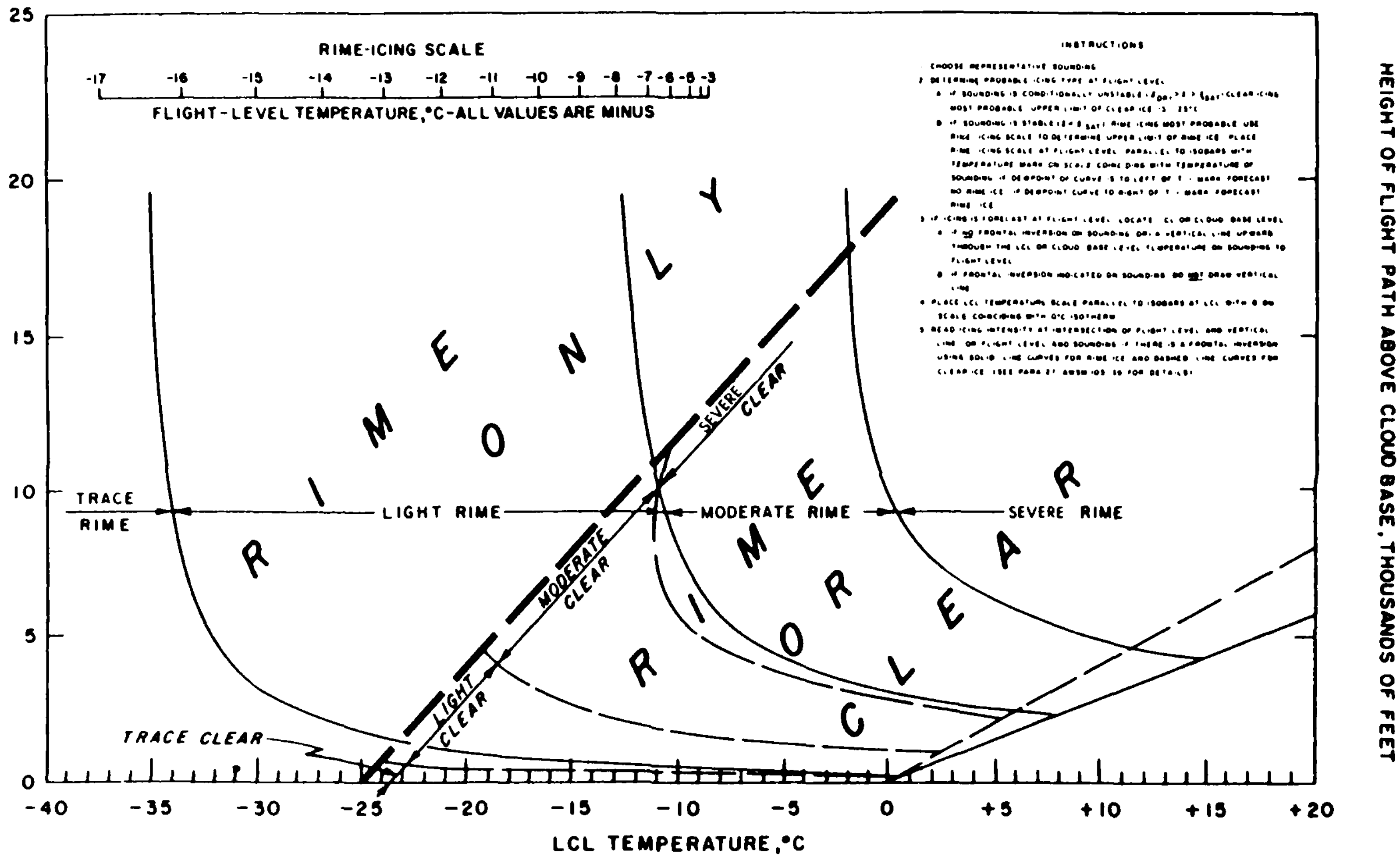

Fig. 7 Overlay for Determining Icing Intensities from Radiosonde Temperature Plots on Skew T-Log P Graphs (from AWS/TR-80/001).

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APPENDIX A. Summary Descriptions of the Cold, Low Ceiling Episodes

1. <u>November 24, 1981.</u>

<u>Surface Analysis (1200z, 0700L*):</u> Widespread cloudiness resulted from a low pressure system centered 250 nmi (460km) to the west of Washington, DC.

<u>Conditions at DCA and BWI:</u>

Ceiling: gradually lowering during the day.

Surface temperature: around +5°C.

Winds: easterly at 8 kt.

Precipitation: light rain or snow.

<u>Conditions at IAD:</u>

Ceiling: less than 1000 ft by 1000L.

Surface Temperature: around 0°C.

Winds: northerly at 4 kt.

Precipitation: light rain or snow.

<u>Icing PIREPS:</u> No icing reported.

<u>Surface Analysis (2400z, 1900L):</u> Low pressure center moving northeastward through the area; weather improving after passage--clear skies by 2200L.

<u>Conditions at DCA and BWI:</u>

Ceiling: around 1000 ft between 1600L and 1900L, rising rapidly after 1900L.

Surface Temperature: around +2°C.

Winds: from 50° at 10 kt, shifting to the north after 1900L.

Precipitation: light rain or snow, ending after 1800L.

<u>Conditions at IAD:</u>

Ceiling: 300-400 ft between 1200L and 1700L, rising to about 1000 ft after 1700L.

Surface temperature: +1°C.

Winds: Northerly at 7 kt, shifting to northwest after 1700L.

Precipitation: light snow or rain, ending after 1700L.

*Local (L) time refers to Eastern Standard Time.

Icing PIREPS: Widespread icing reported from about 5000 ft (1.5km) to above 10,000 ft (3km) during the afternoon and evening. Light to moderate icing was most often reported. Occasional reports of mixed (rime and clear) icing were also noted between 6000 and 8000 ft (2-2.5km).

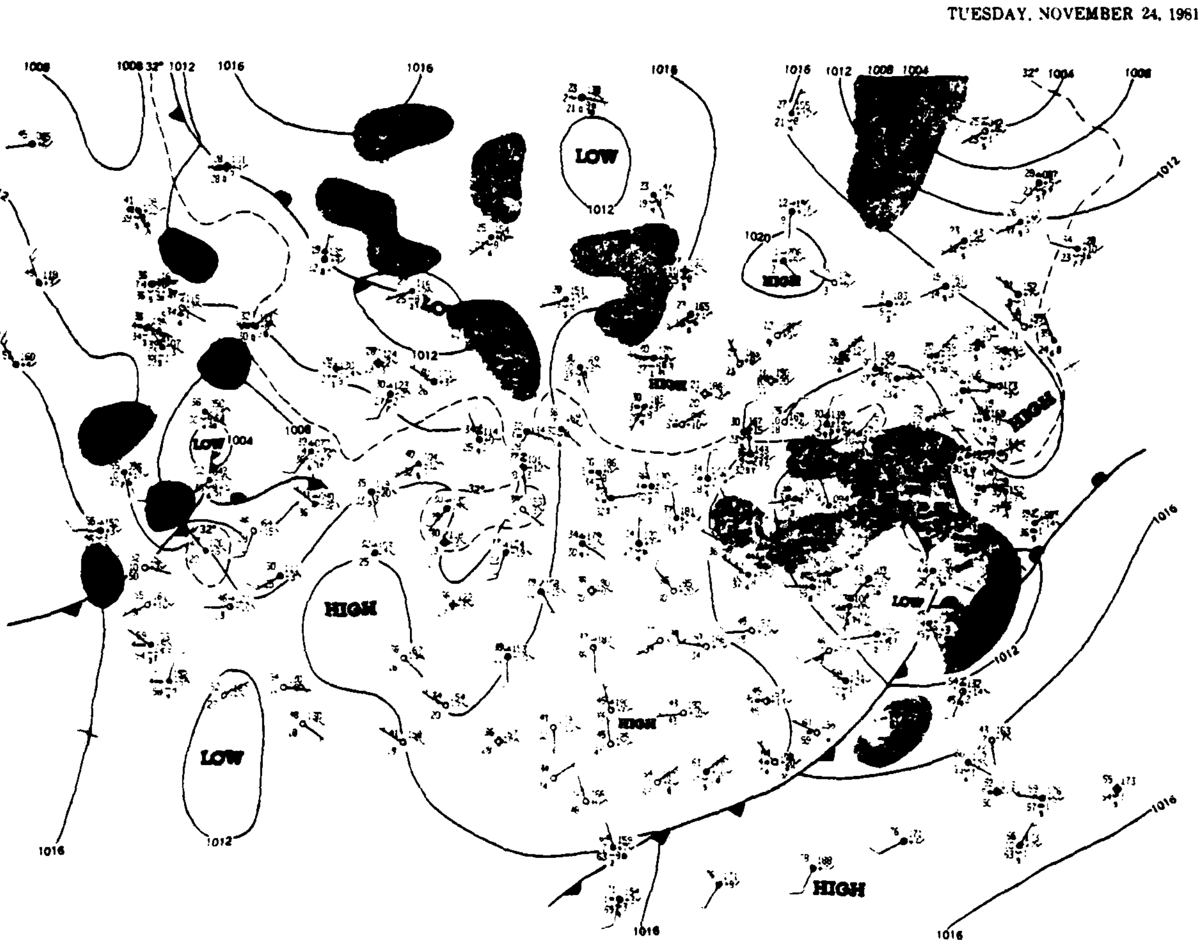

Fig. A-1. Surface weather for Nov. 24, 1981 at 1200 GMT (0700 EST).

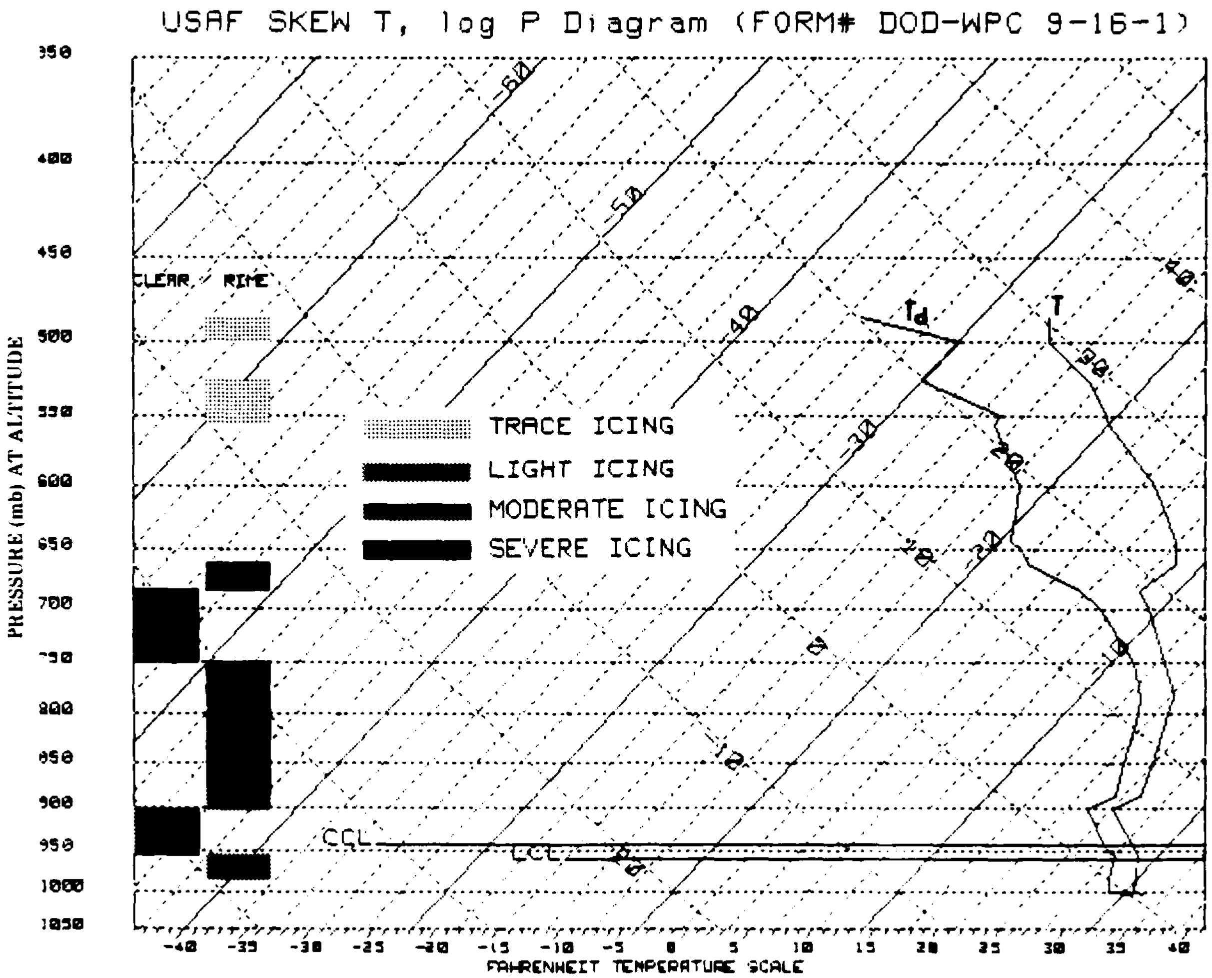

Fig. A-2. Air temperature T, dewpoint temperature Td, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Nov. 24, 1981 at 1100 GMT (0600 EST). (Horizontal lines labeled LCL and CCL are just the routinely computed Lifting Condensation Level and Cloud Condensation Level, respectively. The slightly curved lines running from lower right to upper left are the theoretical, dry-adiabatic lapse rates.)

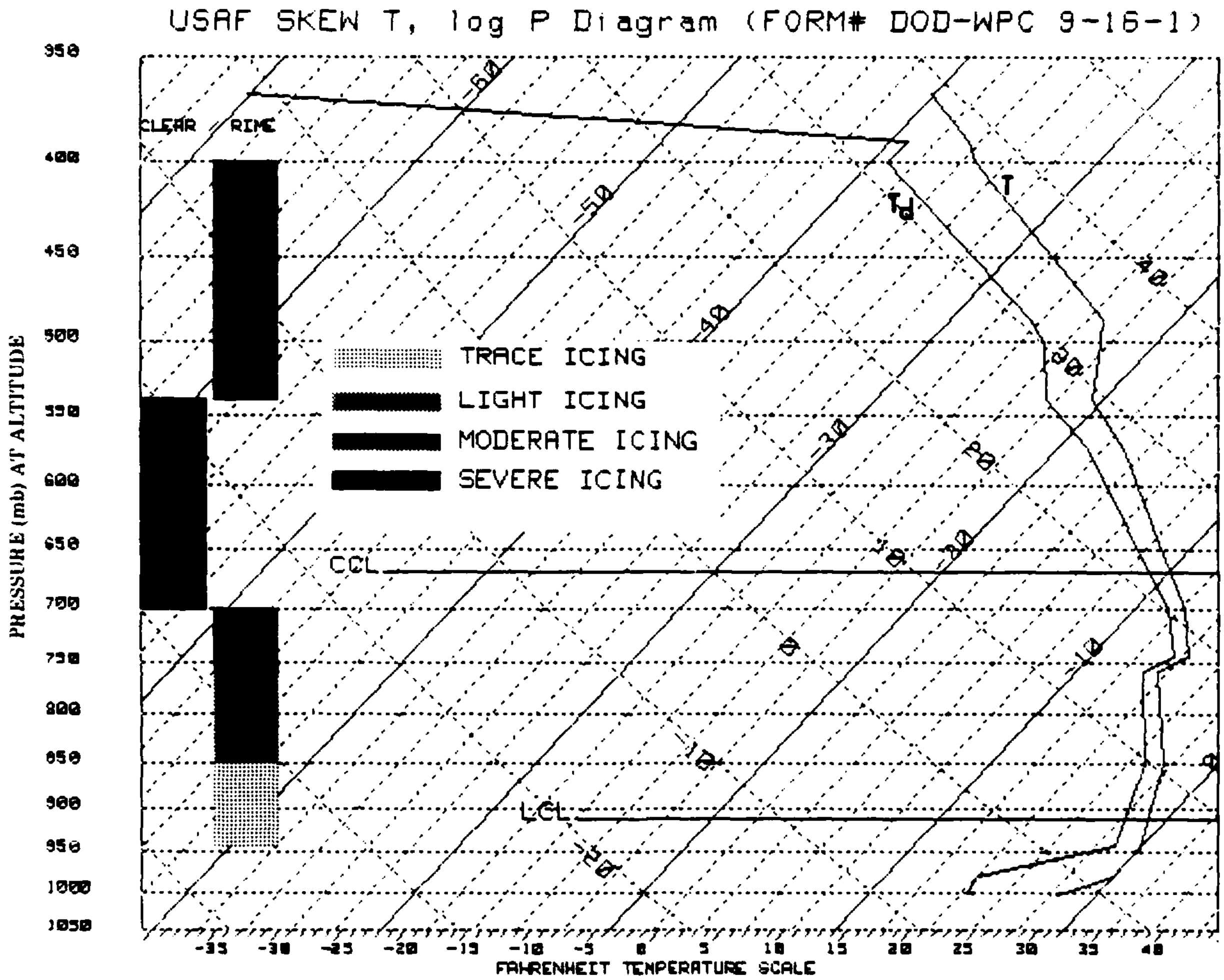

Fig. A-3. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Nov. 24, 1981 at 2300 GMT (1800 EST).

2. December 1, 1981

Surface Analysis (2400z, 1900L): A moderately strong closed-low and occluded front nearby to the west produced widespread cloudiness over the Atlantic coastal states.

Conditions at DCA:

Ceiling: gradually lowering to below 1000 ft by 1400L and to 400 ft between 1700 and 1900L with visibility 1 1/4 miles (2.0km), and ceiling remaining low through midnight.

Surface temperature: around +5°C in afternoon.

Winds: light and variable from the southeast in the morning shifting to 6 kt from 60° during late afternoon, becoming westerly at night.

Precipitation: light rain or drizzle and fog most of day and evening.

Conditions at BWI:

Ceiling: lowering rapidly from 3000 ft to 400 ft at about 1330L. Lowest ceiling (300 ft) and visibility (3/4 mile) were observed between 1700L and 1900L. Clouds remained low through midnight.

Surface temperature: around +5°C in afternoon.

Winds: East-southeast changing to 9 kt from 90° in late afternoon, becoming westerly at night.

Precipitation: light rain and drizzle and fog most of day.

Conditions at IAD:

Ceiling: gradually lowering to below 1000 ft by 1330L. Lowest ceiling (200 ft) and visibility (3/4 mile) occurred between 1700L and 1900L, after windshift from south-east to west-northwest.

Surface temperature: +2°C in afternoon.

Winds: shifting from southeast to west-northwest in afternoon.

Precipitation: light rain and drizzle and fog most of day.

Icing PIREPS: No icing was reported.

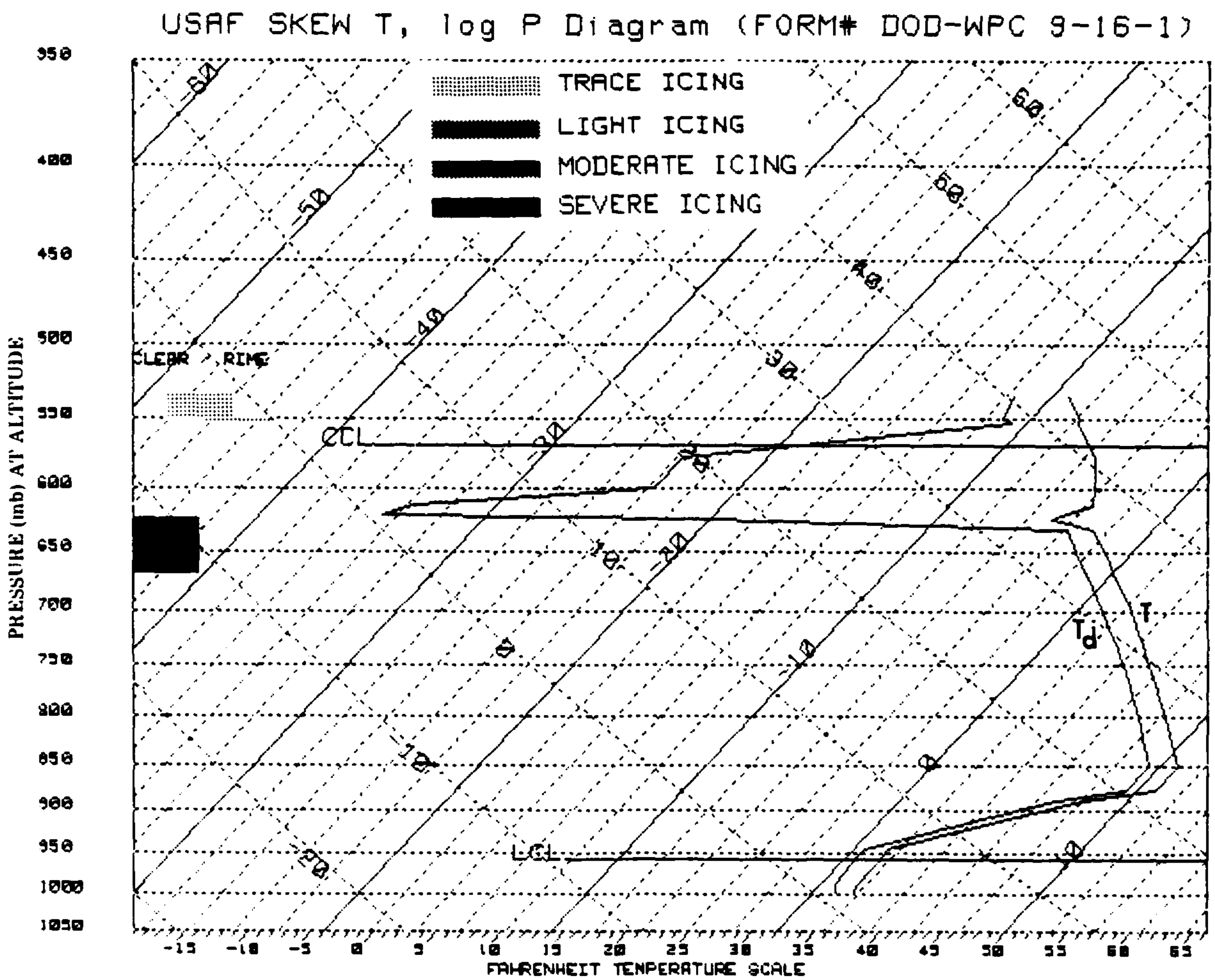

Fig. A-4. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC on Dec. 1, 1981 at 2300 GMT (1800 EST).

3. December 14-15, 1981

Surface Analysis (Dec. 14, 2400z, 1900L): A warm front stretched along the Atlantic seaboard from a low pressure center in Georgia to offshore Cape Cod.

Conditions at DCA, BWI and IAD:

Ceiling: lowering from 4500 ft in late morning to 600 ft in afternoon with visibility down to 1 mile or less.

Surface temperature: 0^{o} to $+4^{o}C$.

Winds: southeasterly in morning changing to northeasterly (30^{o}-50^{o}) in afternoon, shifting to north-northwest around 2400L.

Precipitation: light, steady rain and fog all afternoon and night. (Sleet and freezing rain in northern suburbs of Washington, DC during afternoon).

Icing PIREPS: Light-to-moderate mixed icing reported below 4000 ft during the afternoon, and icing reported above 10,000 ft at night.

Surface Analysis (Dec. 15, 1200z, 0700L). Another low pressure center developed in southern New England along the warm front. The entire east coast was affected by the frontal system now classified as a cold front stretching between the low pressure centers over Georgia and New England.

Conditions at DCA, BWI, and IAD:

Ceiling: generally raised to 1000-2000 ft.

Surface temperature: 0^{o} to $+4^{o}C$.

Winds: from the north-northwest.

Precipitation: steady, light rain and fog from mid morning to mid afternoon.

Icing PIREPS: Moderate icing between 2000-3000 ft was reported around local noon.

Surface Analysis (Dec. 15, 2400z, 1900L): Washington area now in a region of rapidly falling pressure and a strong pressure gradient.

Conditions at DCA, BWI, and IAD:

Ceiling: falling to below 1000 ft with visibility less than 2 miles.

Surface temperature: 0^{o} to $+1^{o}C$ throughout evening and night

Winds: light to 15 kt or more from the north-northwest.

Precipitation: sleet and light to moderate snowfall in the area, with accumulation of 1 to 6 inches.

Icing PIREPS: Light twin engine plane forced to land near BWI at 1100L after developing trouble in both engines after takeoff during snowfall. Elsewhere in the area, light rime icing was reported above 8000 ft.

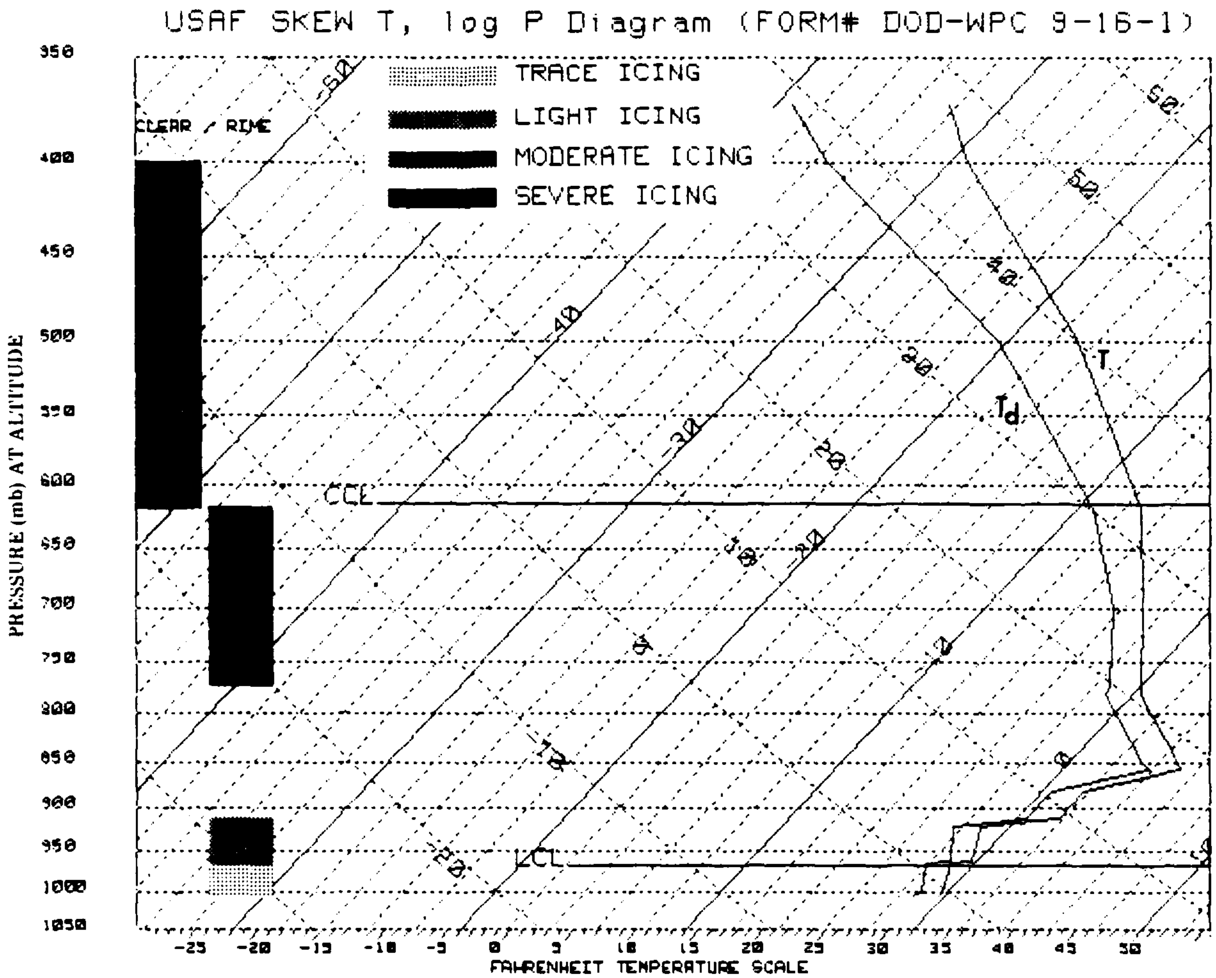

Fig. A-5. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC on Dec. 14, 1981 at 2300 GMT (1800 EST).

TUESDAY, DECEMBER 15, 1981

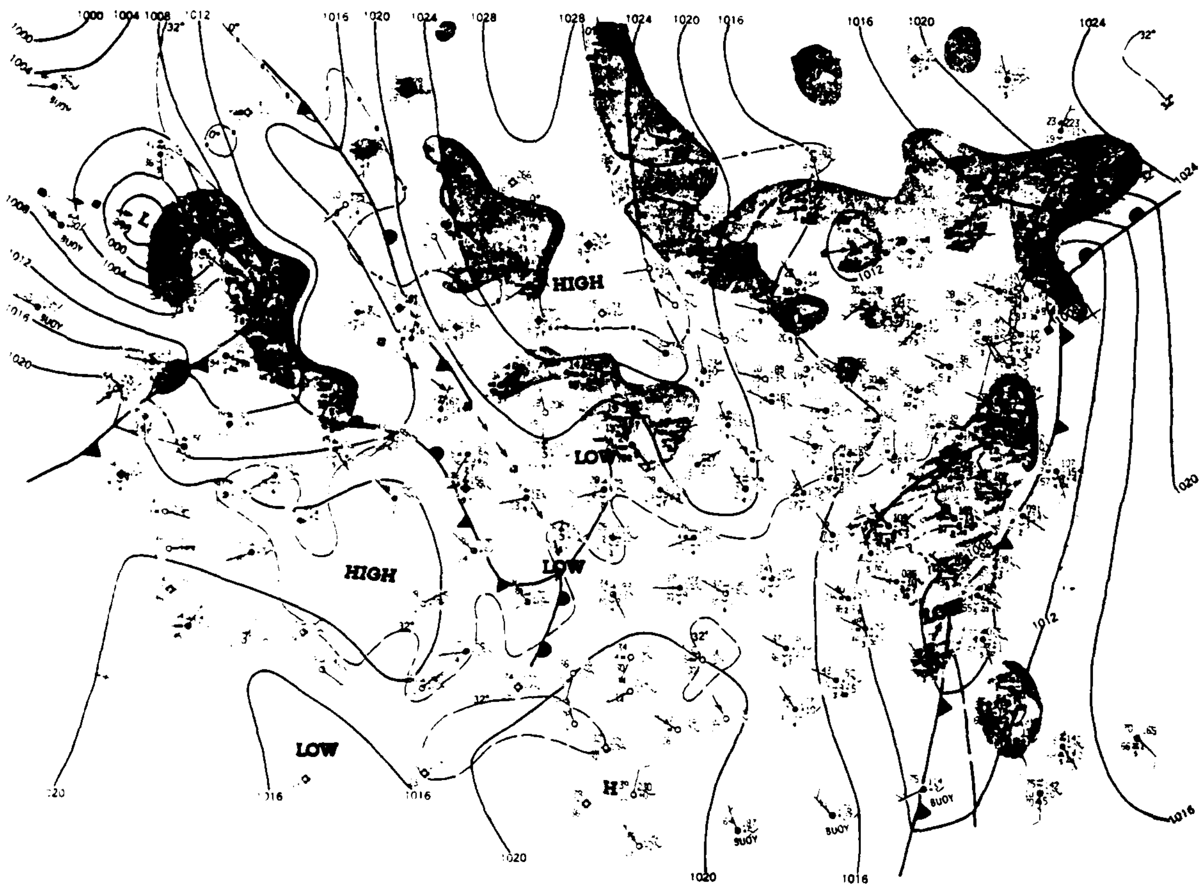

Fig. A-6. Surface weather for Dec. 15, 1981 at 1200 GMT (0700 EST).

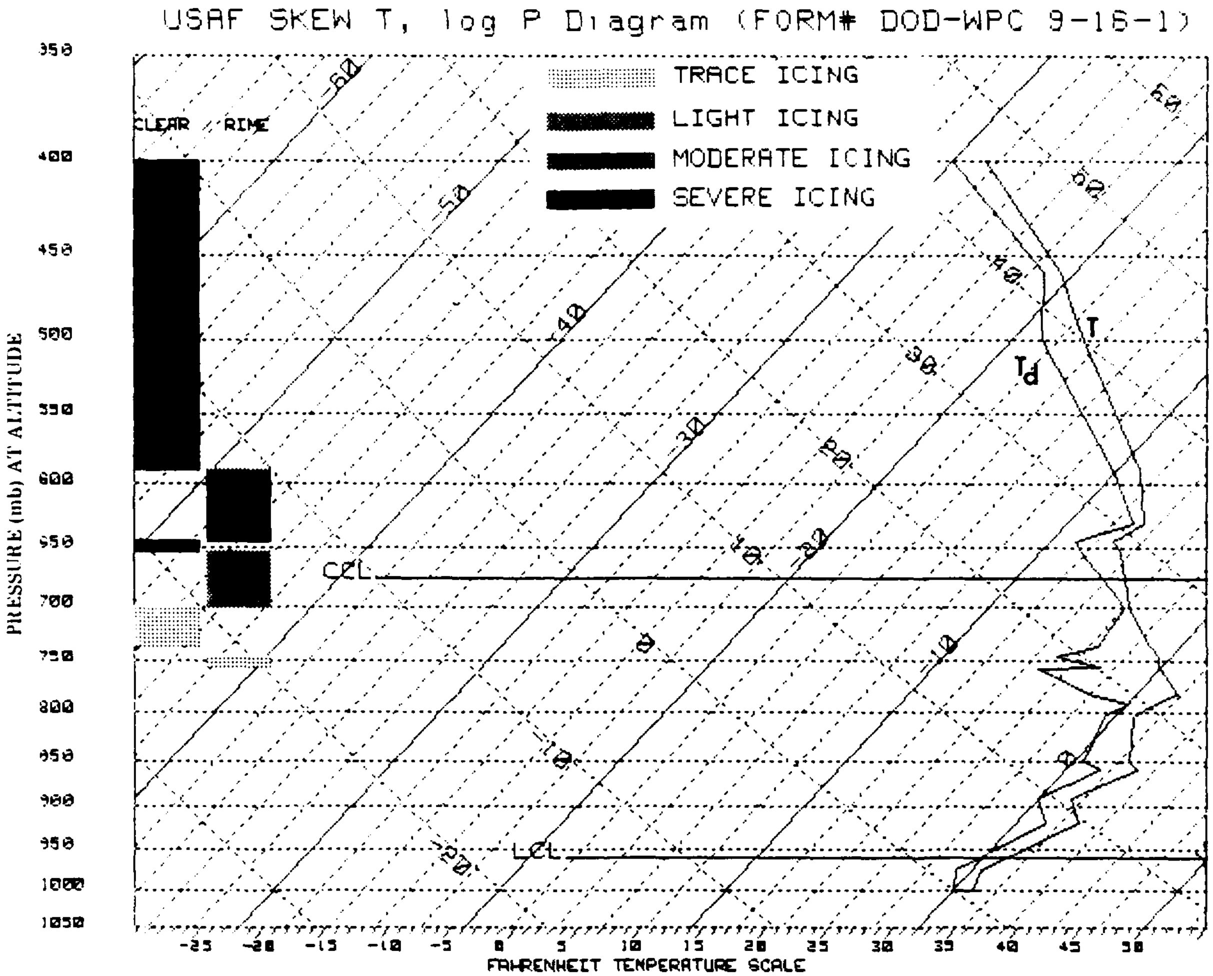

Fig. A-7. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Dec. 15, 1981 at 1100 GMT (0600 EST).

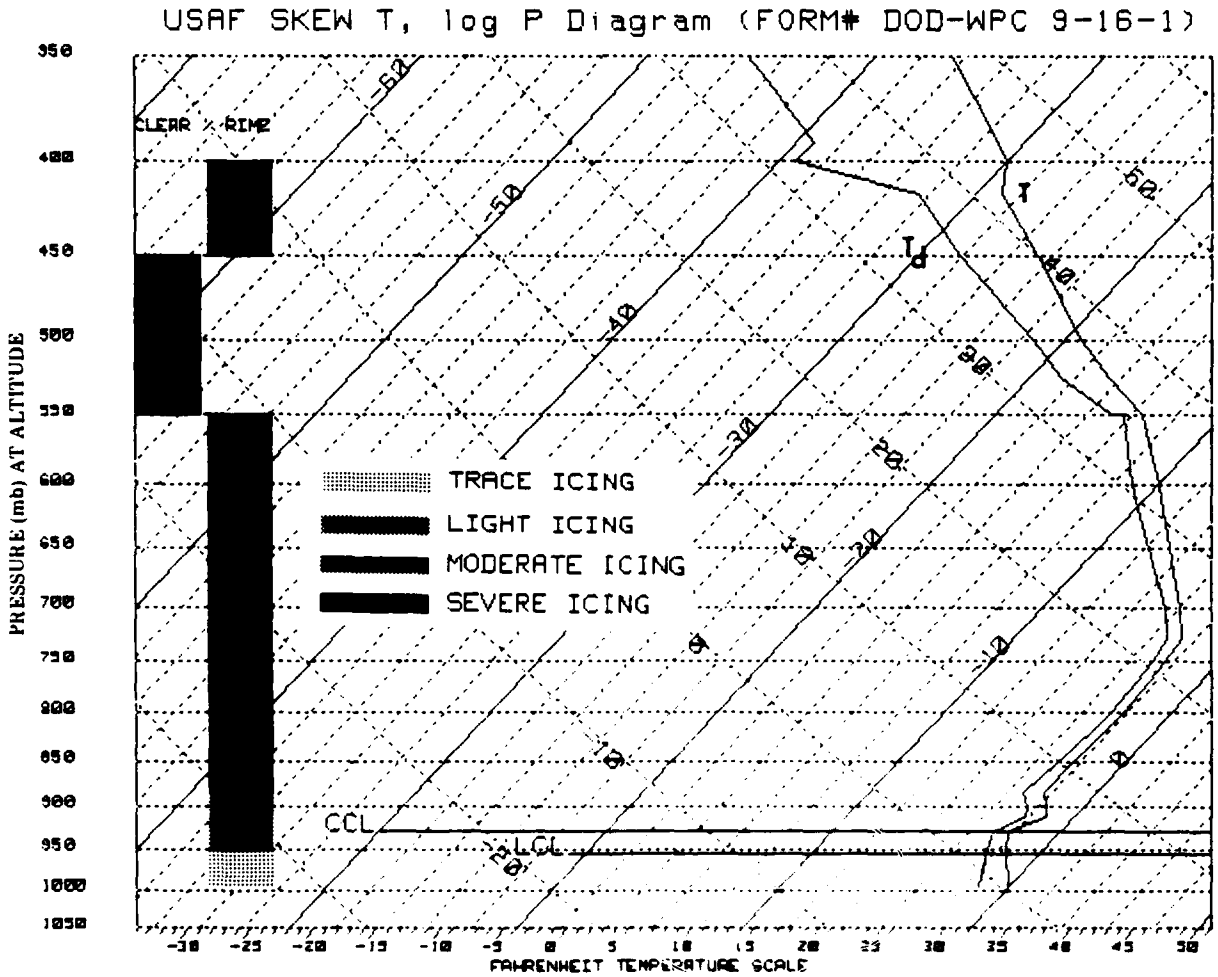

Fig. A-8. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Dec. 15, 1981 at 2300 GMT (1800 EST).

4. December 22, 1981

Surface Analysis (Dec. 22, 2400Z, 1900L):

Conditions at DCA:

Ceiling: lowering to 500 ft by 0900L and remaining below 1000 ft until 1430L.

Surface temperature: $+1^{o}$ to $+3^{o}C$.

Winds: 10 to 15 kt from the south-southwest.

Precipitation: rain, sleet, and snow ending by 0700L.

Conditions at BWI:

Ceiling: 600 to 1000ft between 0500 and 1500L.

Surface temperature: +2 to $+4^{o}C$.

Winds: 10 to 15 kt from the southwest.

Precipitation: light rain ending by 1100L.

Conditions at IAD:

Ceiling: about 700 ft until 1400L.

Surface temperature: $+3^{o}C$.

Winds: 10 to 15 kt from the south southwest.

Precipitation: light rain ending by 0900L.

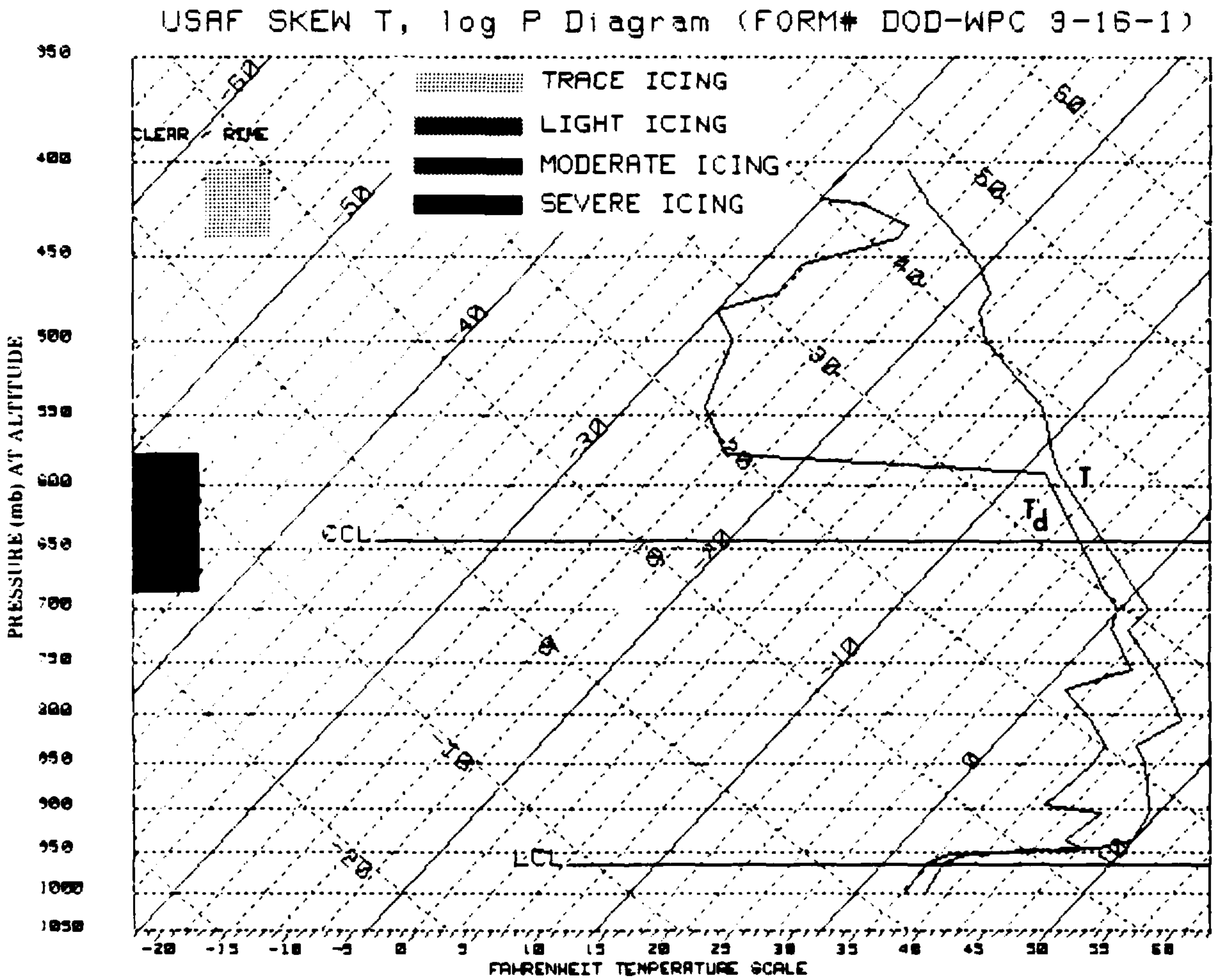

Fig. A-9. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Dec. 22, 1981 at 2300 GMT (1800 EST).

5. January 3-4, 1982

Surface Analysis (Jan. 3, 2400z, 1900L): A frontal wave some 100 mi south of the Washington, DC area, and a developing low pressure system over the southern states brought widespread cloudiness to the eastern third of the country.

Conditions at DCA:

Ceiling: around 200 ft until 0600L, Jan. 4; lowest ceiling was 100 ft at 0300L, Jan. 4.

Winds: light from 50° until 0600L.

Surface temperature: around +4°C.

Precipitation: rain and fog.

Conditions at BWI:

Ceiling: around 200 ft and 1/4 mile visibility until 0600L, Jan. 4.

Surface temperature: around +4°C.

Winds: from 70° at 7 kt.

Precipitation: rain and fog.

Conditions at IAD:

Ceiling: around 200 ft and 3/4 mile visibility until 0600L.

Surface temperature: around +2°C.

Precipitation: rain and fog

Icing PIREPS: No icing reported, but a light, twin-engined plane crashed with engine trouble near Richmond, VA at 1700L in rain and a very low ceiling. All eight people aboard were killed.

Surface Analysis (Jan. 4, 1200z, 0700L): The developing low pressure system was now a strong, closed, low pressure center over the Great Lakes area, with a convoluted warm front meandering through the middle Atlantic states. Changes (alternate improvements and worsening) of sky conditions were associated with the meandering of the warm frontal zone in and around the Washington, DC area throughout the morning and afternoon.

Conditions at DCA and BWI:

Ceiling: lifting to about 1800 ft with windshift at 0600L, but dropping to 700 ft again after 1000L. Skies clearing after 1730L.

Surface temperature: around +7° to +10°C.

Winds: shifting to 250° at 0600L, gradually shifting to south-southeasterly by 1000L, then becoming southwesterly. Windspeed was light at the surface, but was up to 65 kt above 6000 ft when out of the south. At 1730L, winds became northwesterly.

Precipitation: Raining throughout the early morning hours until about 0800L. There were a couple of occurrences of lightning and thunder over DC at about 0730L.

Conditions at IAD:

Ceiling: generally 300 ft or lower with visibility mostly between 3/4 and 2 miles. Skies began clearing after 1600L.

Surface temperature: +2° to +6°C gradually rising to +10°C by about 1600L.

Winds: light or calm at the surface, becoming westerly after 1600L.

Precipitation: steady rain until around 1600L.

Icing PIREPS: Moderate to severe rime icing reported between 9000-11,000 ft around 1600-1700L west of IAD.

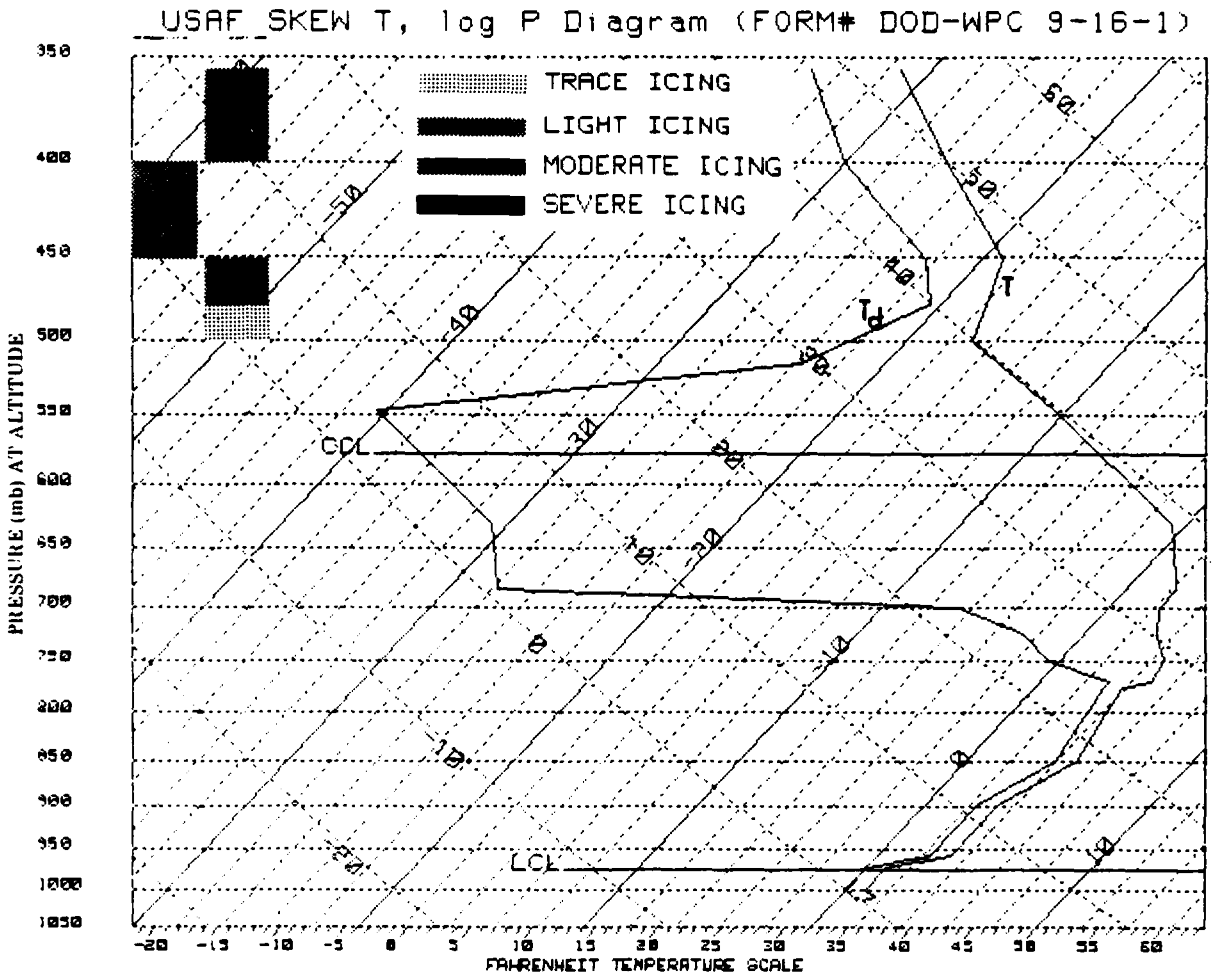

Fig. A-10. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 3, 1982 at 2300 GMT (1800 EST).

MONDAY, JANUARY 4, 1982

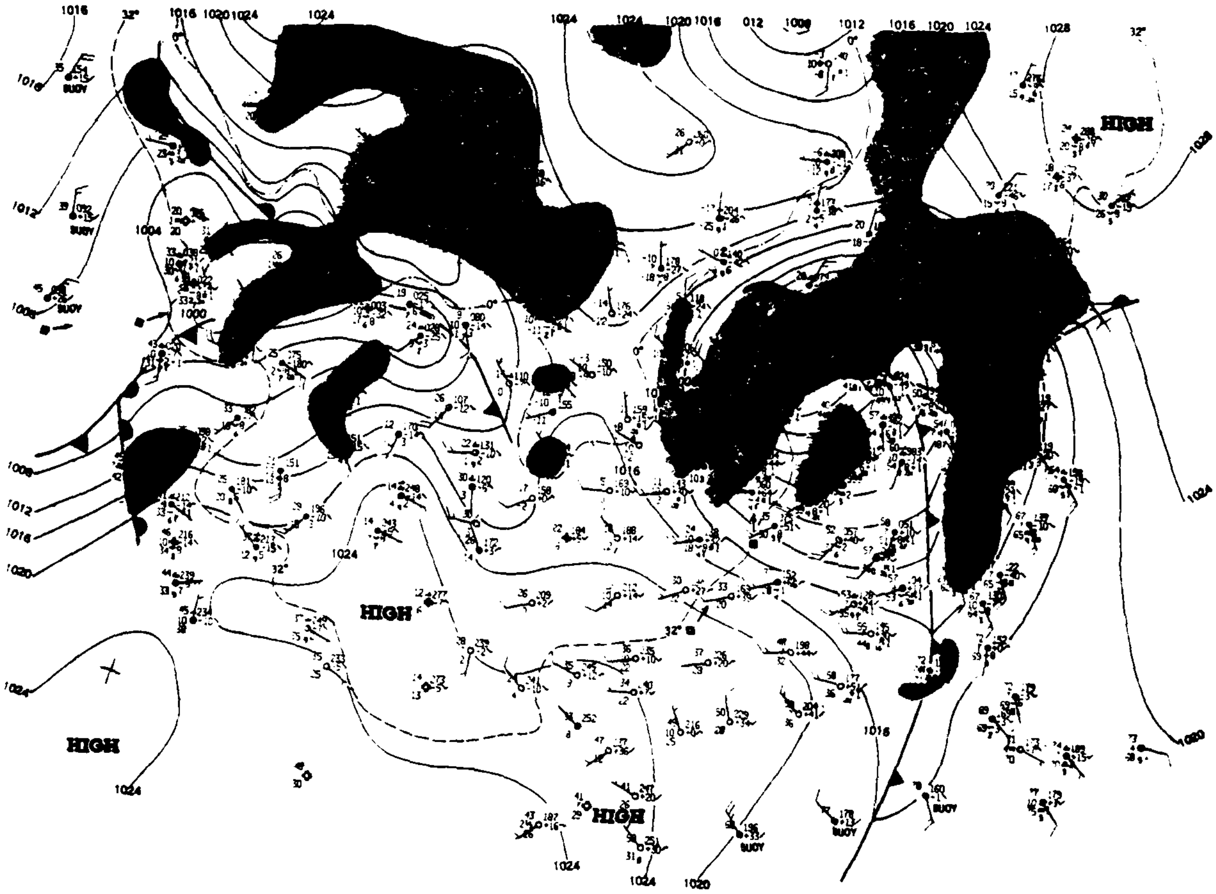

Fig. A-11. Surface weather for Jan. 4, 1982 at 1200 GMT (0700 EST).

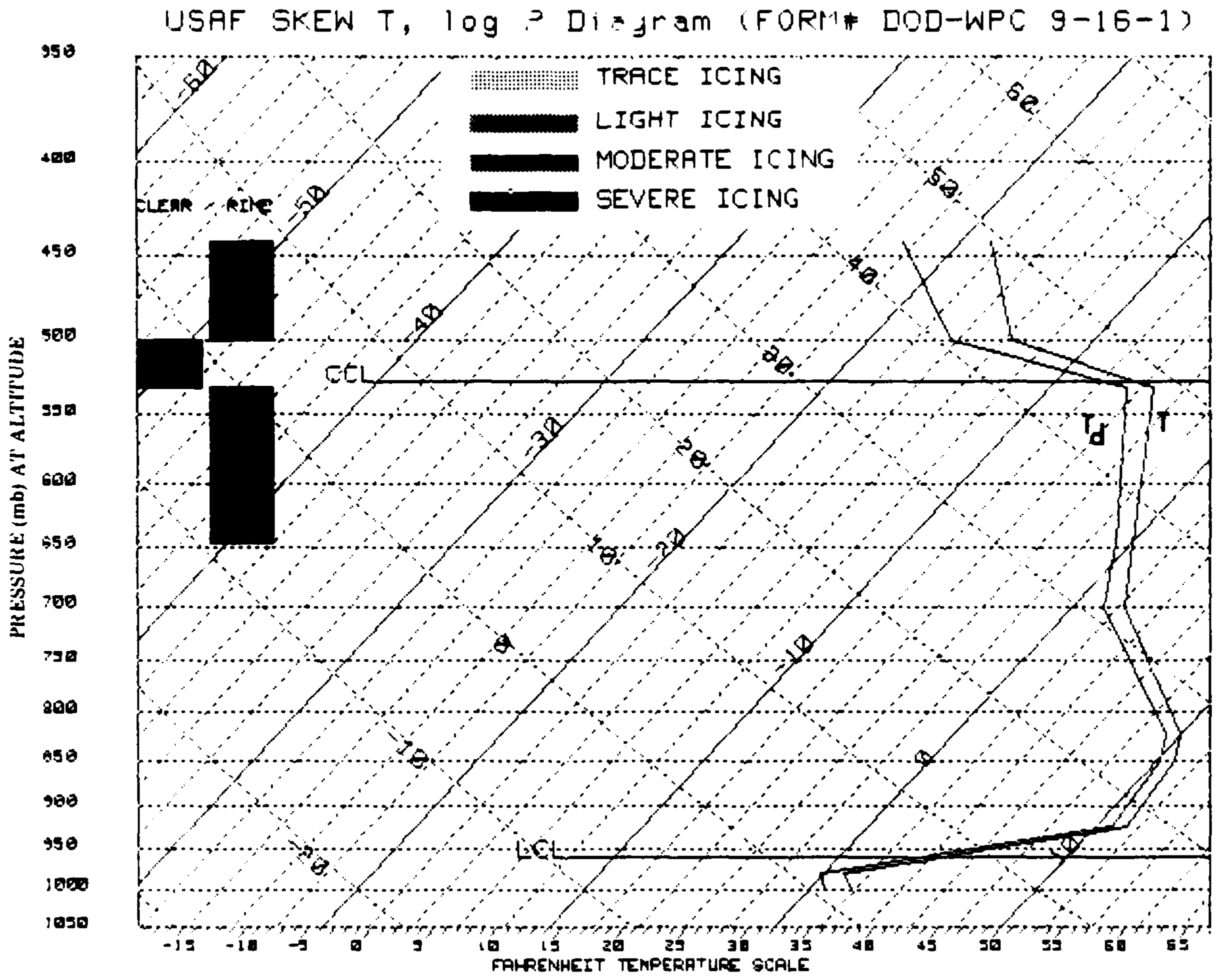

Fig. A-12. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 4, 1982 at 1200 GMT (0700 EST).

6. January 13, 1982.

Surface Analysis (1200z, 0700L): Developing low pressure system over the southeastern states, with a trough extending northward along the east coast produced snowfall in the middle Atlantic states throughout most of the day. Pressure steadily decreased with the most rapid decrease occurring in the afternoon.

Conditions at DCA, BWI, and IAD:

Ceiling: generally below 1500 ft. Lowest ceilings (500 ft) and 1/4 mile visibilities occurred with northeast winds.

Surface temperature: around $-3^{o}C$.

Winds: gradually shifting throughout the day from the southeast to the northeast to the north.

Precipitation: snow fell continuously after 0200L. This was the day the Air Florida plane crashed in the Potomac River during the snowstorm in the early afternoon.

Icing PIREPS: Reports of icing were over the mountains to the west of Washington. During the afternoon, light to moderate rime icing was reported between 5000 and 6000 ft, and above 8000 ft.

WEDNESDAY, JANUARY 13, 1982

Fig. A-13. Surface weather for Jan. 13, 1982 at 1200 GMT (0700 EST).

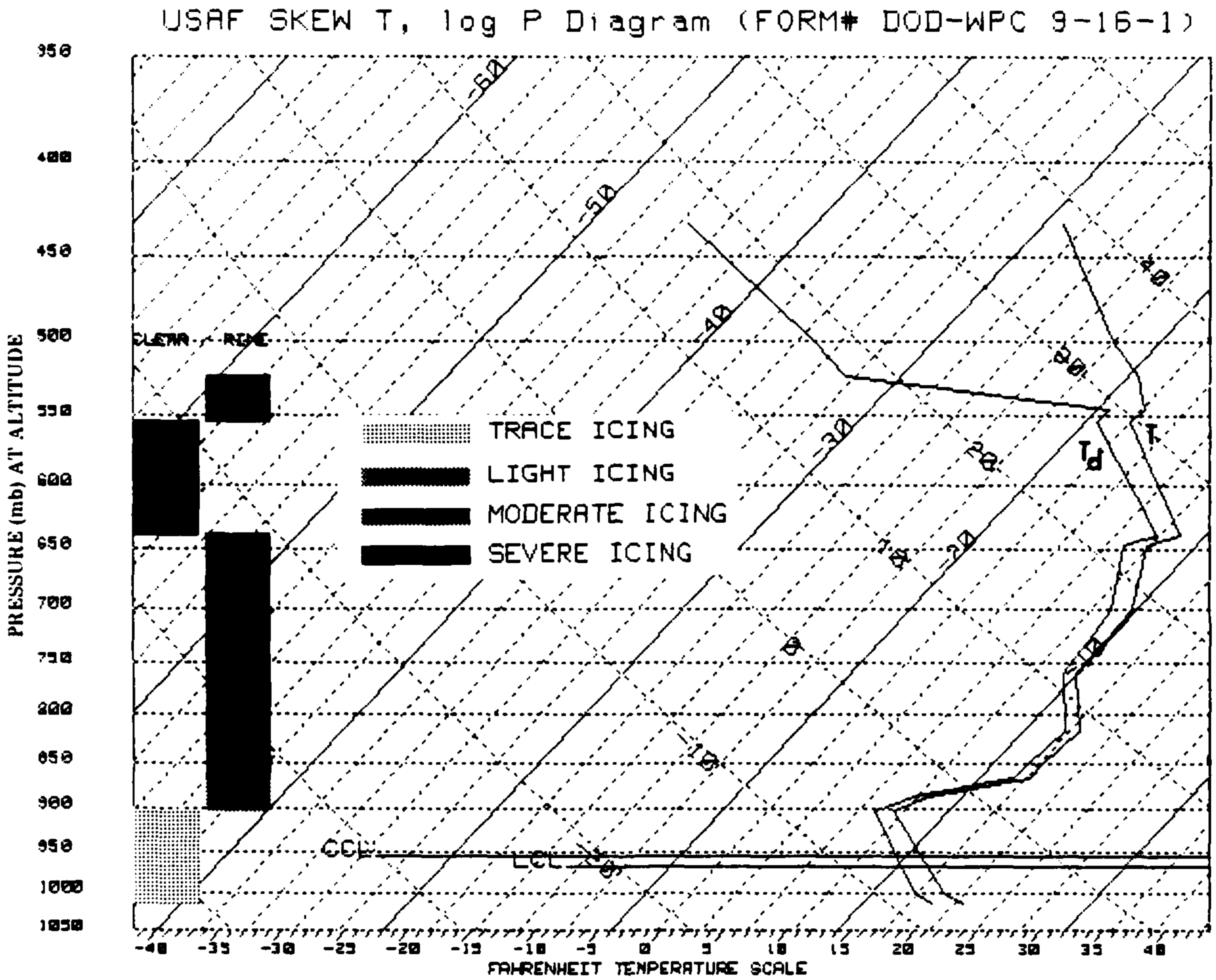

Fig. A-14. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 13, 1982 at 1100 GMT (0600 EST).

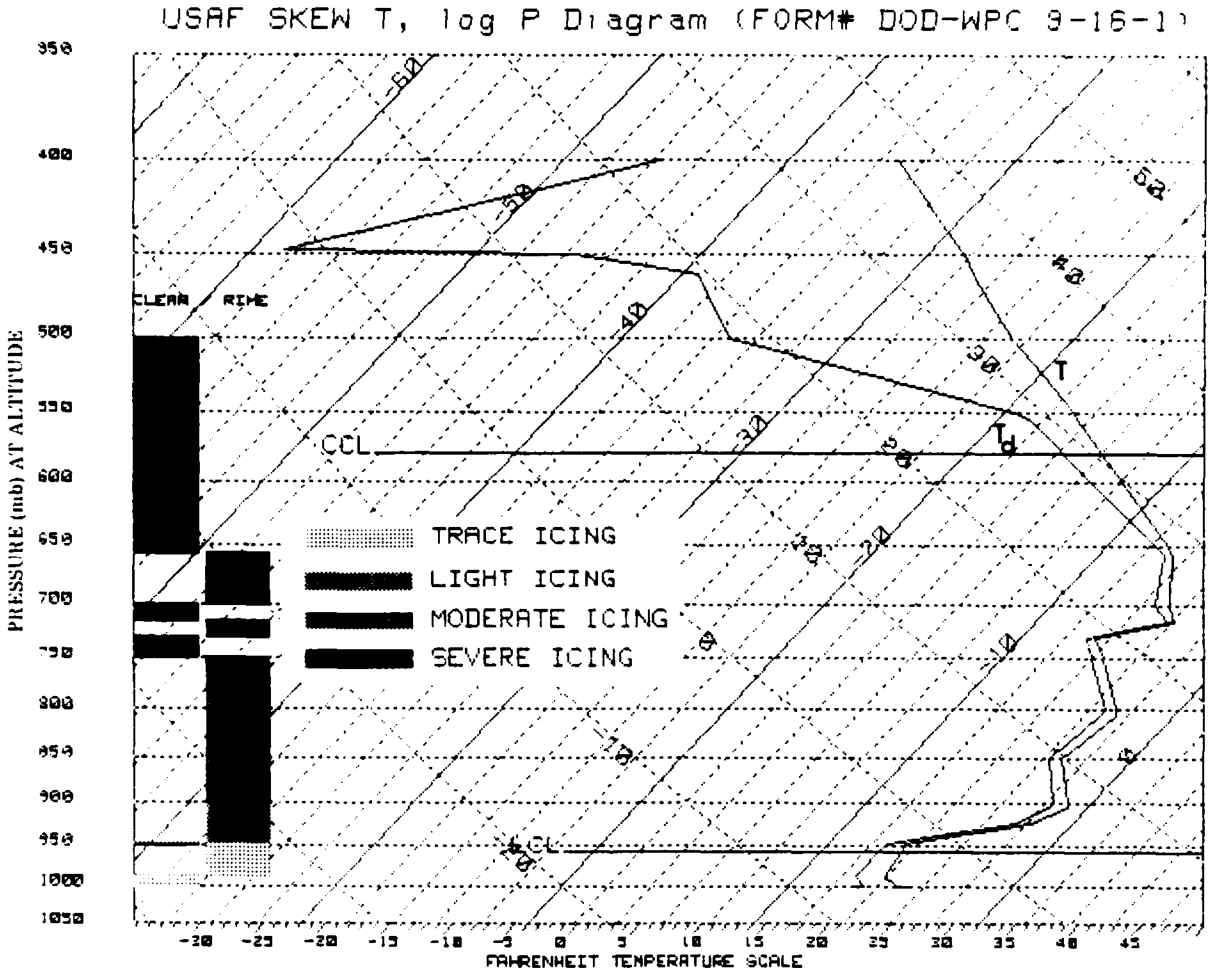

Fig. A-15. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 13, 1982 at 2300 GMT (1800 EST).

7. January 21-22, 1982

Surface Analysis (Jan. 21, 1200z, 0700L): A frontal wave over the southeastern states and a complex of weak low pressure centers 200-300 miles to the west and south.

Conditions at DCA, BWI and IAD:

Ceiling: below 1500 ft and occasionally below 1000 ft.

Surface temperature: around $-3^{o}C$.

Winds: 12 kt or less, generally from the northeast, more variable at IAD.

Precipitation: light snow.

Icing PIREPS: None reported.

Surface Analysis (Jan. 21, 2400z and 1900L): Frontal wave to the south and trough to the west persist in the area.

Conditions at DCA, BWI, and IAD:

Ceiling: around 1300 ft.

Surface temperature: around $-3^{o}C$.

Winds: northwest at about 7 kt.

Precipitation: none.

Icing PIREPS: Moderate to severe rime and mixed icing was reported below 6000 ft during the evening.

Surface Analysis (Jan. 22, 1200z and 0700L): Frontal features still in the vicinity but gradually rising pressures from 1033mb to 1040mb during the morning under the influence of the southern edge of a high pressure system moving eastward along the Canadian border.

Conditions at DCA, BWI and IAD:

Ceiling: gradually lifting to around 3000 ft during the morning, thinning for a while in mid afternoon.

Surface temperature: around $-4^{o}C$.

Winds: light (5-10 kt) from north-northeast.

Precipitation: snow (up to 2 inches) in the area during the early morning hours; snow ending around sunrise.

Icing PIREPS: None reported.

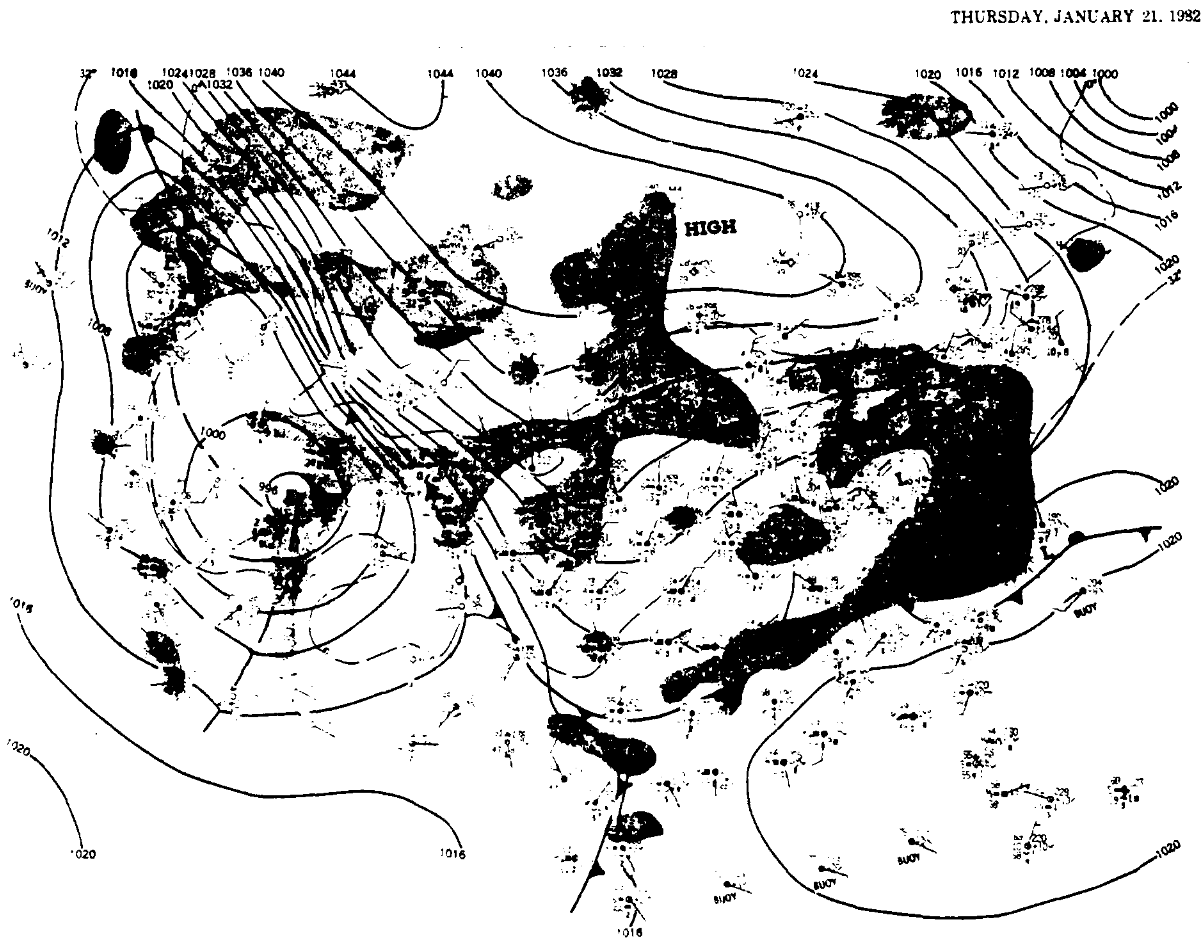

Fig. A-16. Surface weather for Jan. 21, 1982 at 1200 GMT (0700 EST).

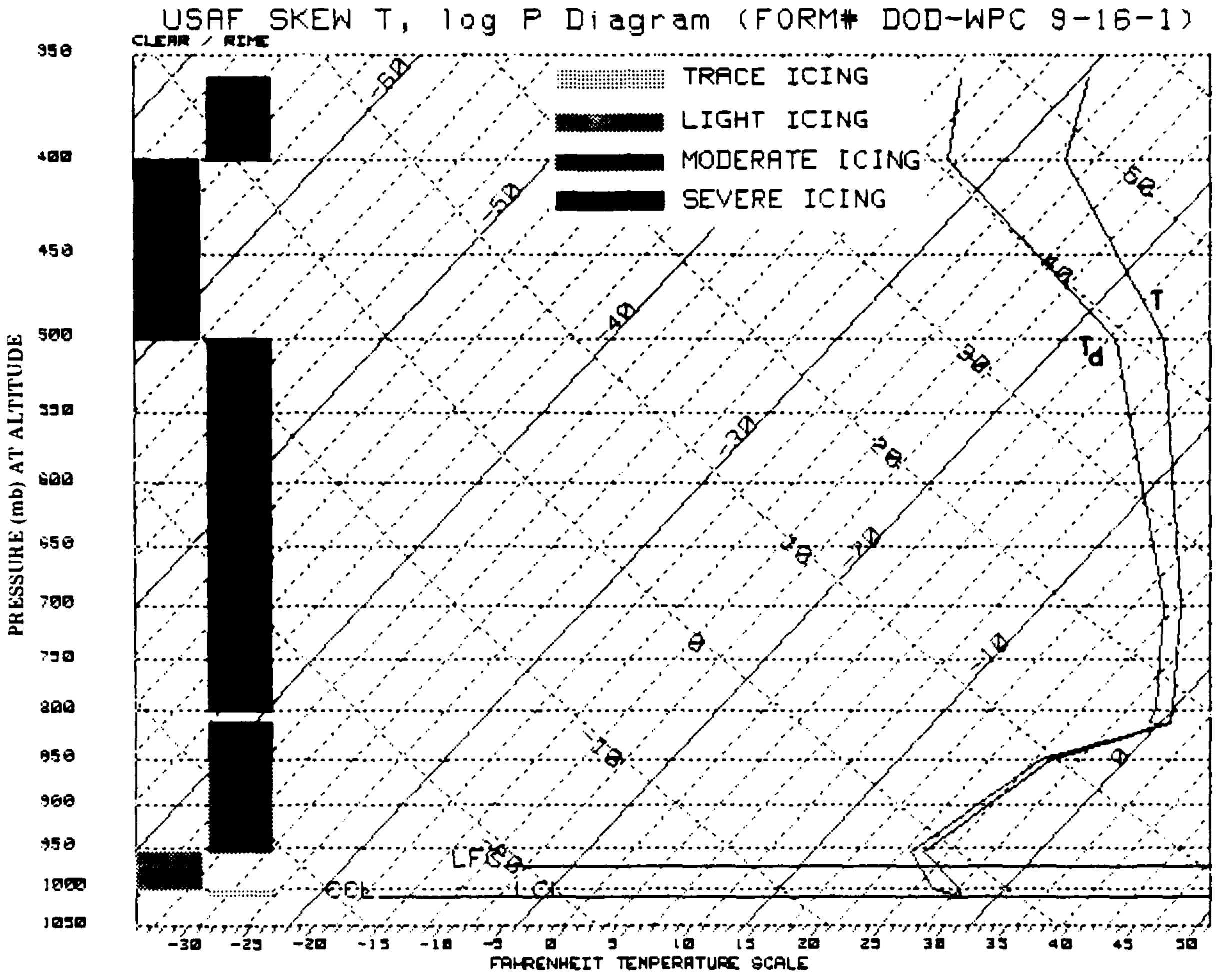

Fig. A-17. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 21, 1982 at 1100 GMT (0600 EST).

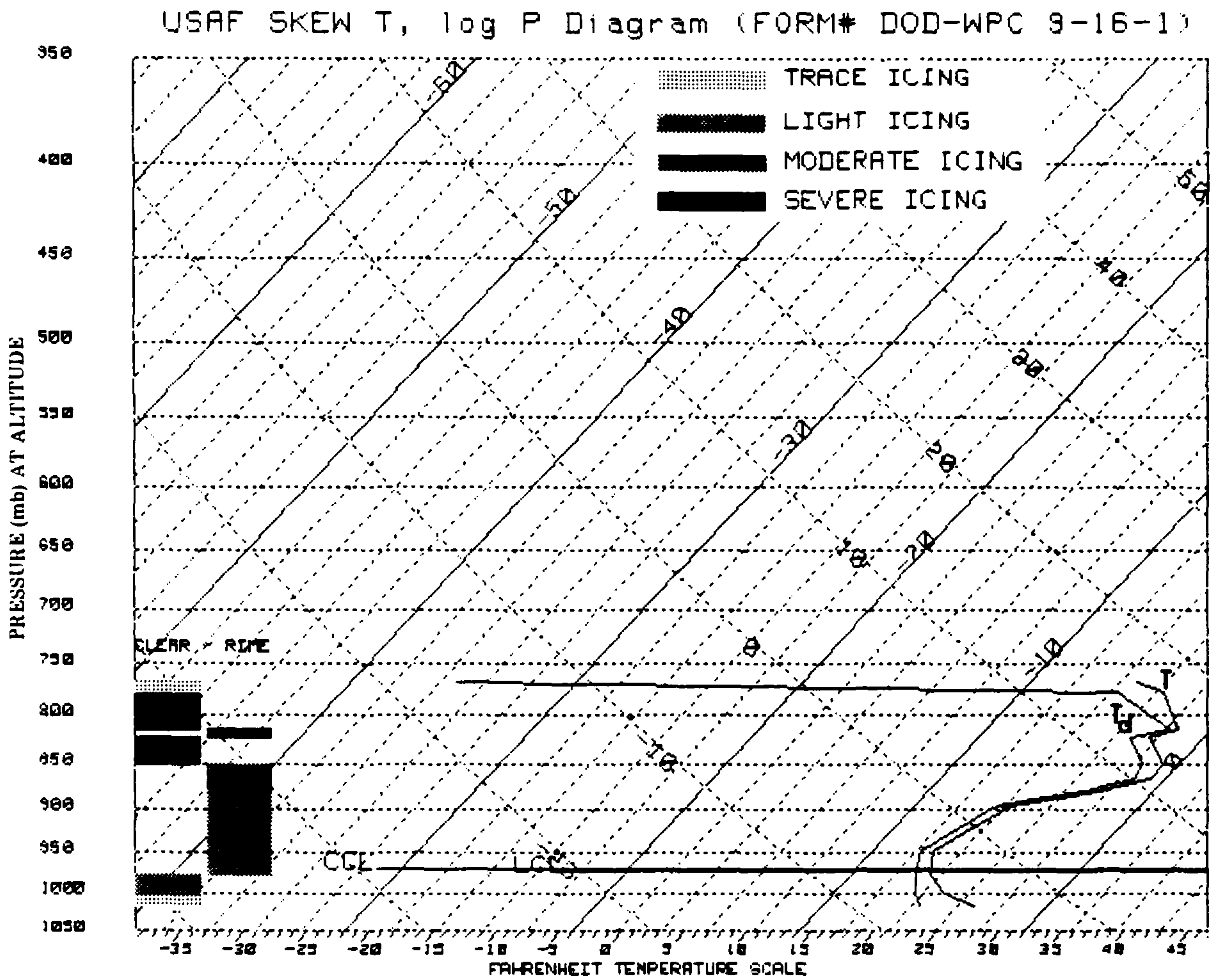

Fig. A-18. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 21, 1982 at 2300 GMT (1800 EST).

FRIDAY, JANUARY 22, 1982

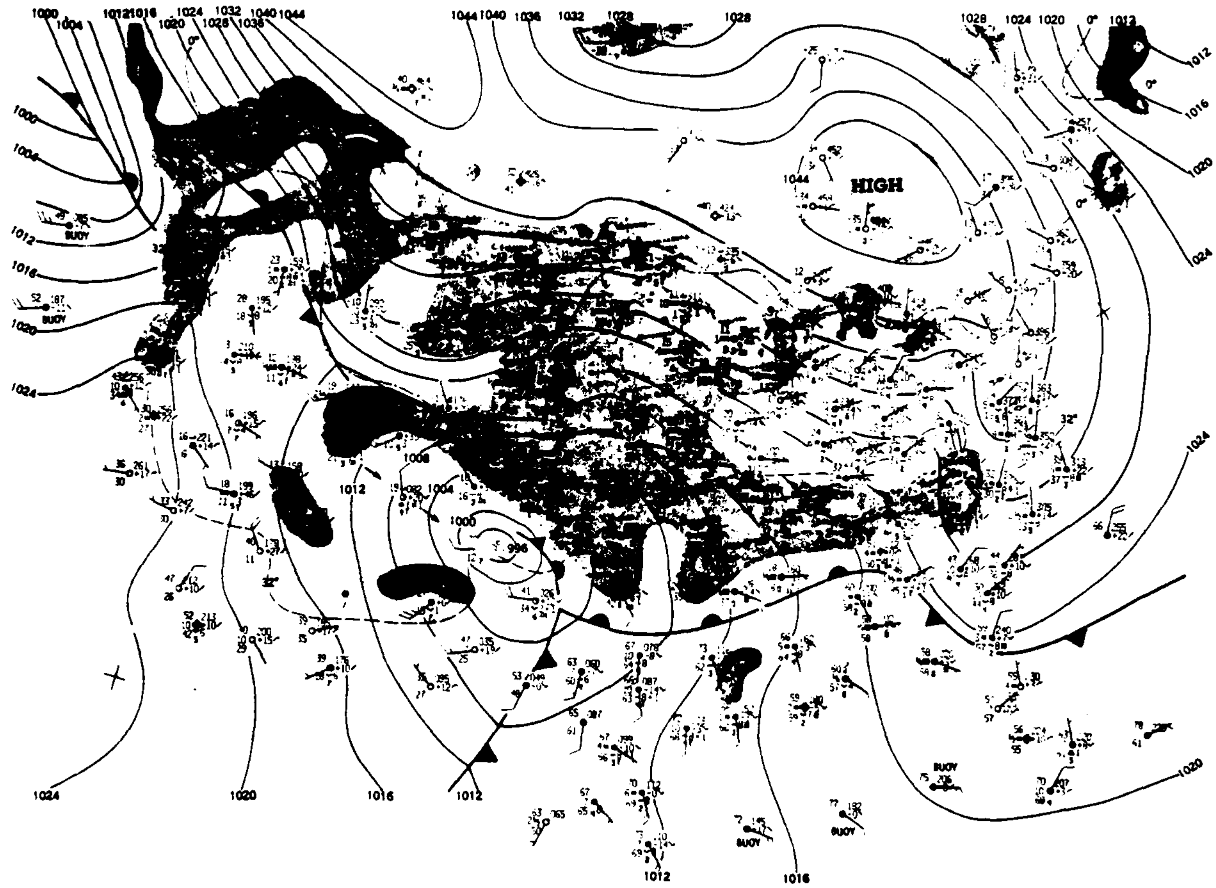

Fig. A-19. Surface weather for Jan. 22, 1982 at 1200 GMT (0700 EST).

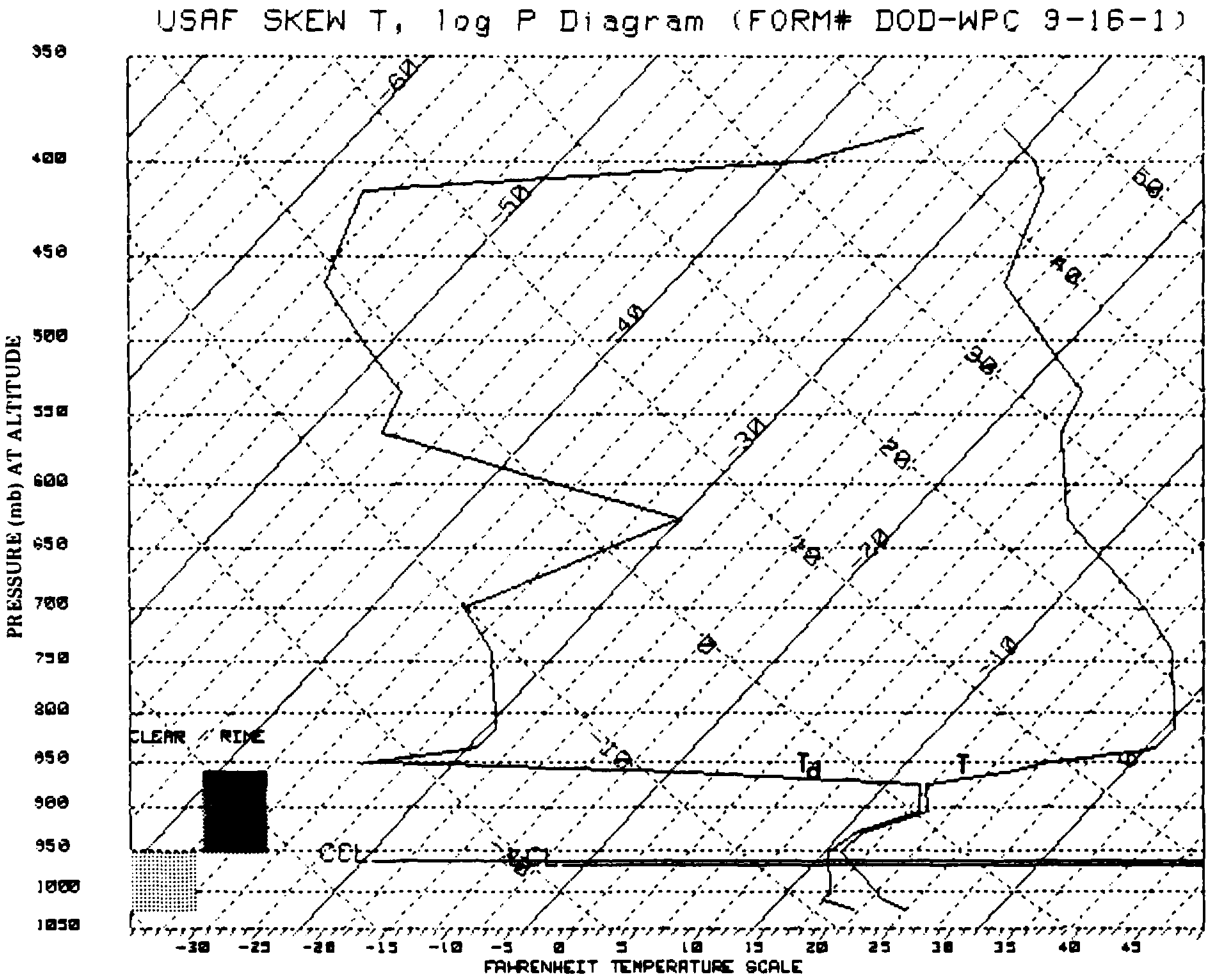

Fig. A-20. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Jan. 22, 1982 at 1100 GMT (0600 EST).

8. February 2-3, 1982

Surface Analysis (Feb. 2, 2400z, 1900L): Long warm front stretching along shoreline of southeastern states and diverting out to sea at Cape Hatteras.

Conditions at DCA, BWI and IAD:

Ceiling: around 500 ft.

Surface temperature: around 0°C.

Wind: nearly calm.

Precipitation: intermittent rain.

Surface Analysis (Feb. 3, 1200z, 0700L): Weak frontal wave centered along the New Jersey coast, and a separate low pressure trough 200-300 miles to the west produced widespread low ceilings, light rain or drizzle, and fog, with visibilities less than 3 miles.

Conditions at DCA, BWI and IAD:

Ceiling: around 500 ft with visibility up to 3 miles, but ceiling lowering to 100-200 ft when oscillating visibility dropped to about 3/4 miles.

Surface temperature: 0° to +2°C in the area.

Winds: calm.

Precipitation: intermittent rain with freezing rain in the northern Maryland counties.

Icing PIREPS: None reported.

Surface Analysis (Feb. 3, 2400z, 1900L): Variable winds and pressures indicated that oscillating conditions were caused by a series of mesoscale waves passing through the area.

Conditions at DCA, BWI and IAD:

Ceiling: lowest (100-200 ft) with 1/8 mile visibility from about 1500-1715L.

Surface temperature: gradually rising during the day to about +3.5°C by 1900L.

Winds: light but shifting from west to southeast during the lowest ceilings and visibilities; otherwise light and variable.

Precipitation: light drizzle and fog.

Icing PIREPS: None reported.

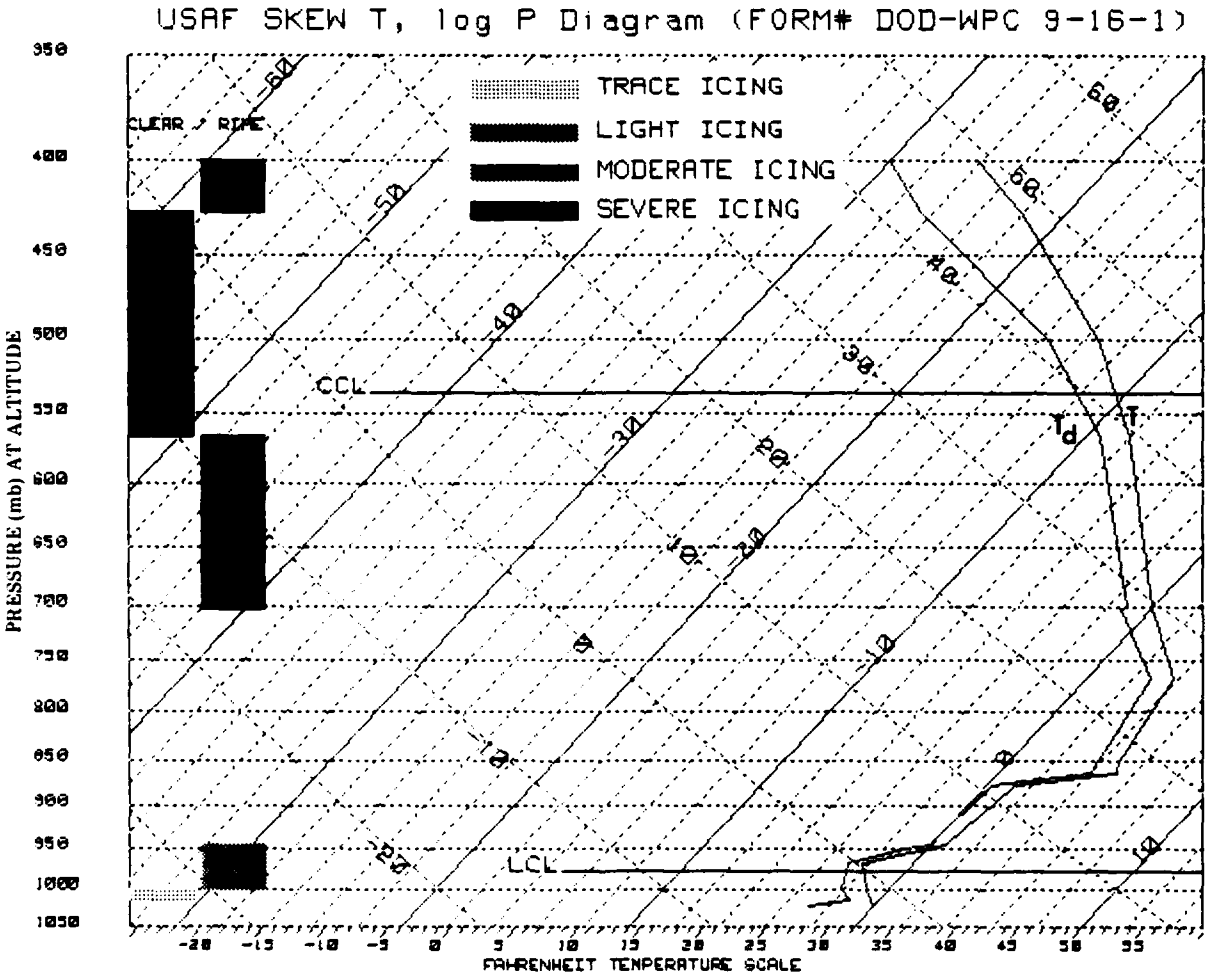

Fig. A-21. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Feb. 2, 1982 at 2300 GMT (1800 EST).

WEDNESDAY, FEBRUARY 3, 1982

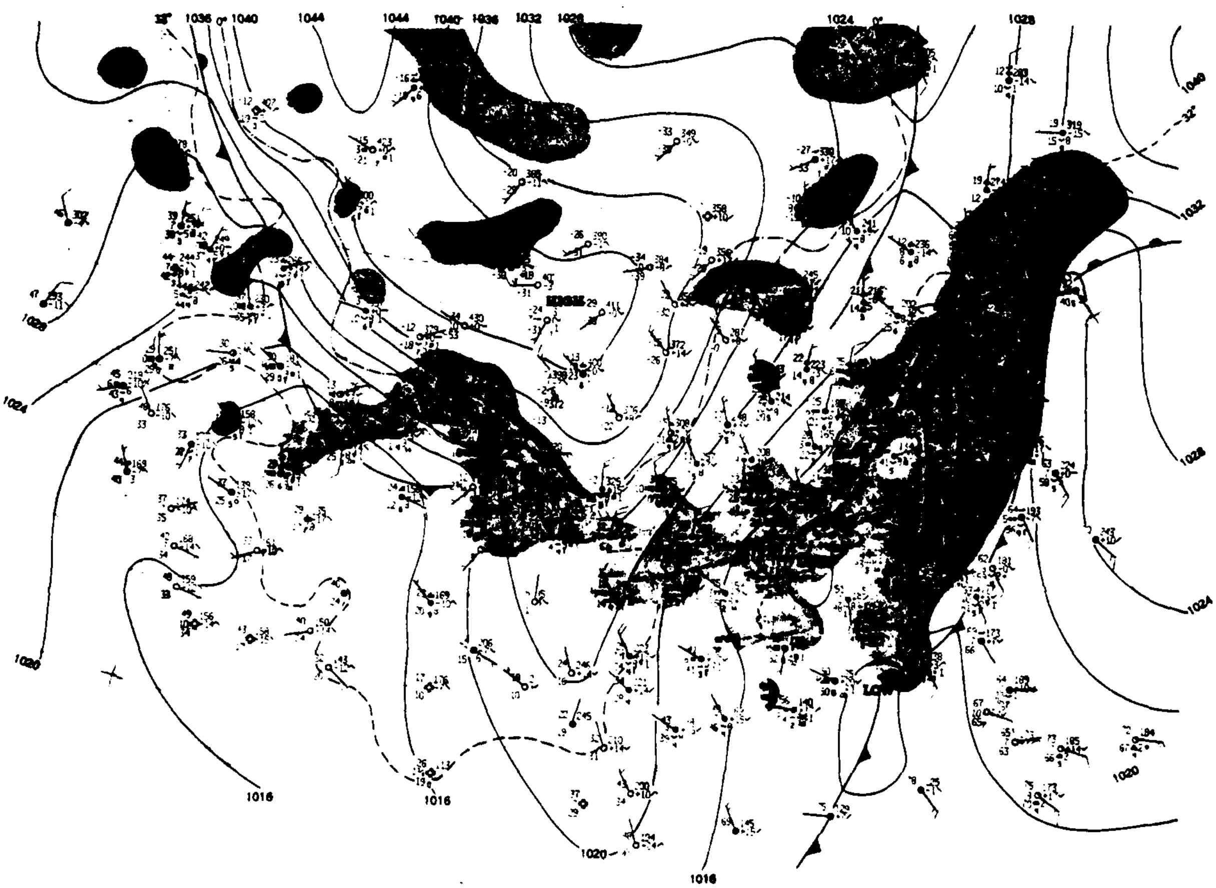

Fig. A-22. Surface weather for Feb. 3, 1982 at 1200 GMT (0700 EST).

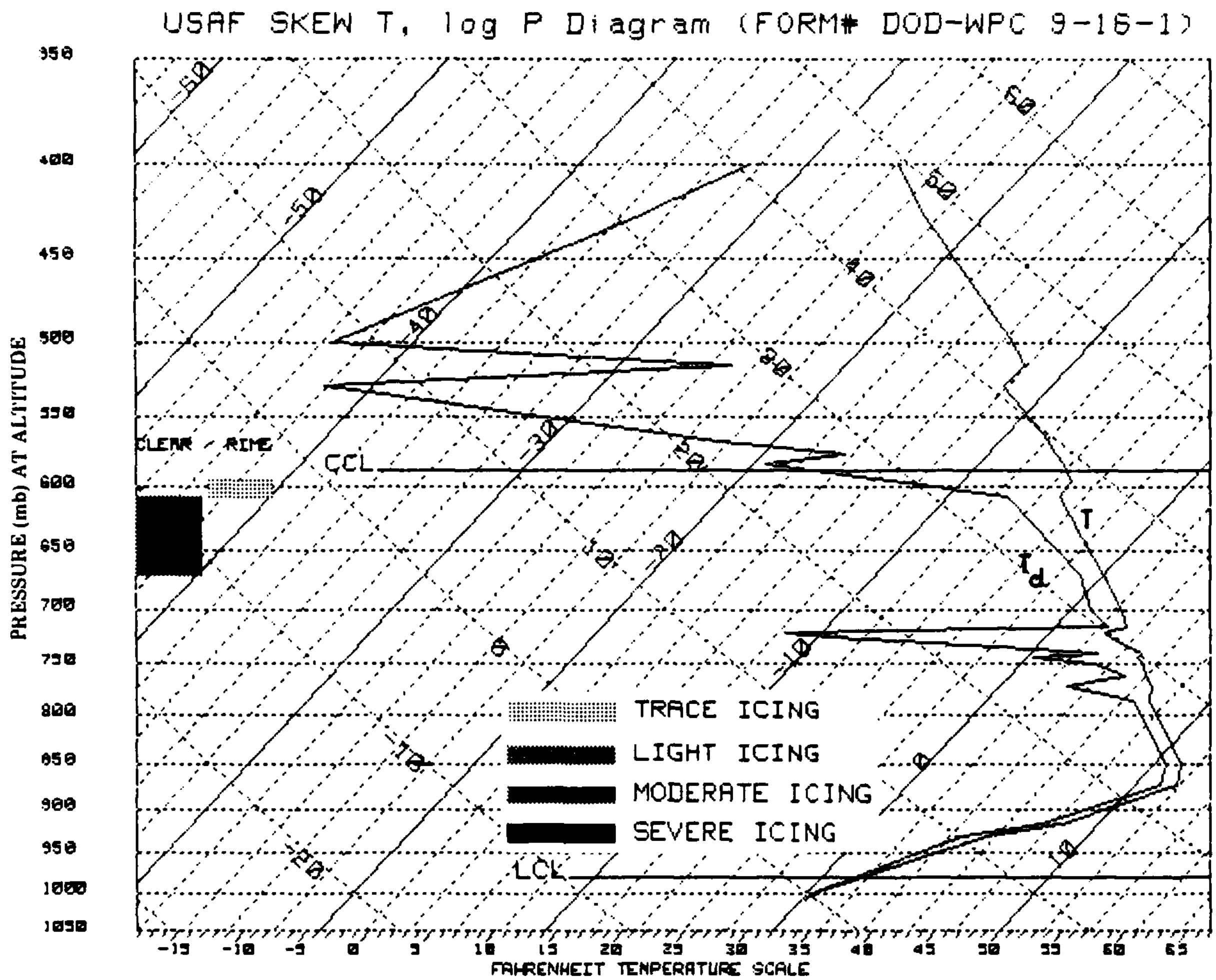

Fig. A-23. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Feb. 3, 1982 at 1100 GMT (0600 EST).

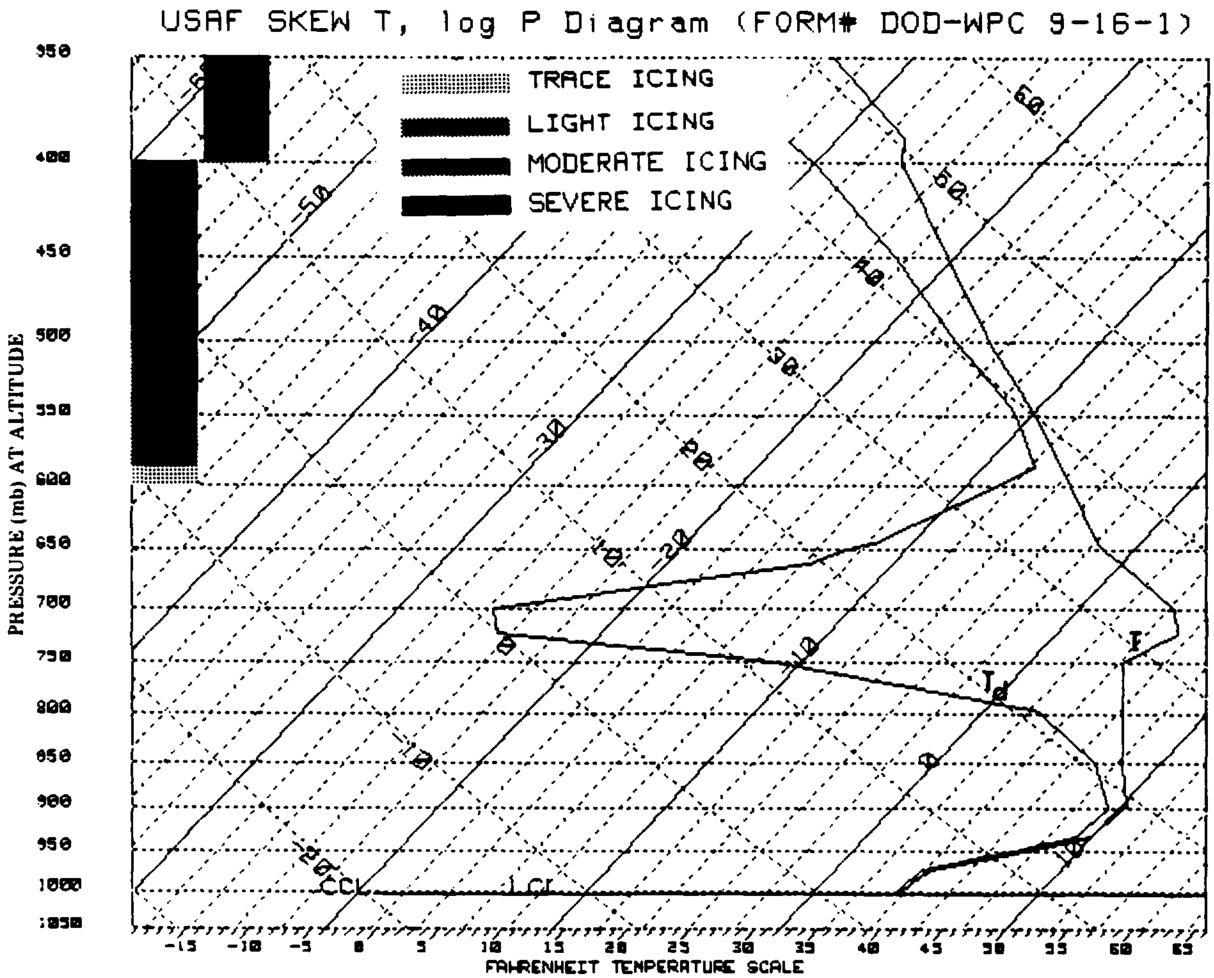

Fig. A-24. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Feb. 3, 1982 at 2300 GMT (1800 EST).

9. February 9, 1982.

Surface Analysis (1200z, 0700L): Warm front 100 miles south, low pressure trough 100 miles west, and weak low pressure center (frontal wave) 200 miles southwest, brought a mixture of snow, freezing rain, and rain. Pressure dropping from 1020 to 1008mb between 0100-1500L, rising after 1700L.

Conditions at DCA and IAD:

Ceiling: about 1000 ft or higher.

Surface temperature: around $+3^{\circ}C$.

Winds: calm, to light (5-10 kt) from the southeast.

Precipitation: about 1 inch of sleet fell in the northern suburbs between 0200 and 0600L.

Conditions at BWI:

Ceiling: dropping to below 1000 ft after 0900L, visibility less than 2 miles.

Surface temperature: 0° to $+3^{\circ}C$.

Winds: calm to light (5-7 kt) from the southeast.

Precipitation: light snow and rain

Icing PIREPS: None reported.

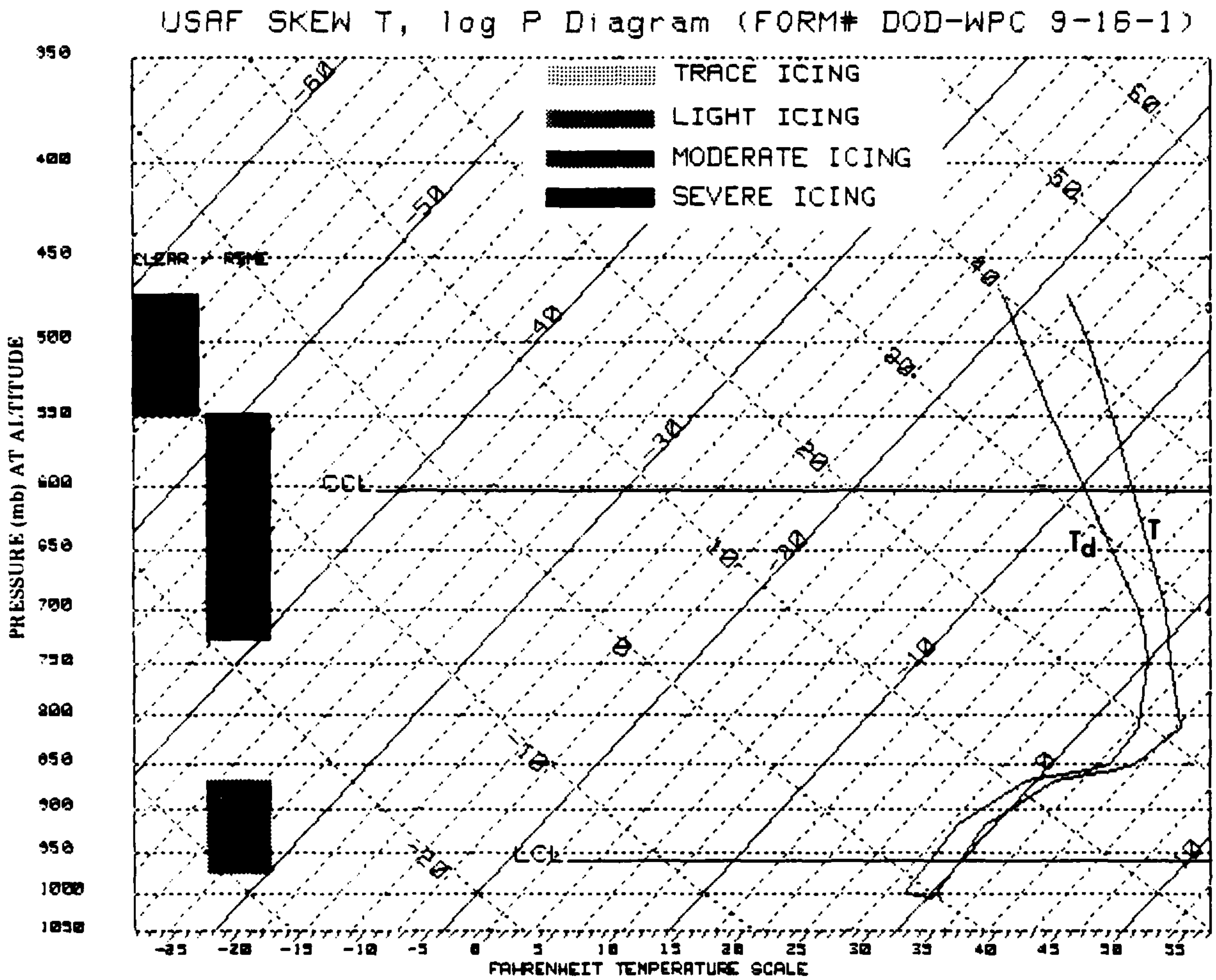

Fig. A-25. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Feb. 9, 1982 at 1100 GMT (0600 EST).

10. <u>February 17, 1982</u>

Surface Analysis (2300z, 1900L): Frontal waves and weak low pressure centers 200-300 miles to the south and a trough 200 miles west brought rain in the morning and afternoon turning to sleet and snow as the temperatures steadily dropped to 0°C or below. Pressure rising steadily from 1015mb at 0900L to 1021mb at 2400L under the influence of a building high pressure system in eastern Canada.

Conditions at DCA:

Ceiling: ragged at around 1000 ft with solid overcast at 1300-2000 ft.

Surface temperature: around +1 °C.

Winds: 10-20 kt from the north.

Precipitation: moderate rain all afternoon turning to light, steady sleet at 1600L, turning to snow in the area by about 1800L with 4 inch accumulation.

Conditions at BWI:

Ceiling: lowest (500 ft) with visibility only 3/4 mile when winds were steady from 50°.

Surface temperature: around -3°C.

Winds: 9 kt. from 50°

Precipitation: light snow accumulating to 4 inches.

Conditions at IAD:

Ceiling: persistent at 400-700 ft.

Surface temperature: around 0°C.

Winds: 5-10 kt varying from north to northeast.

Precipitation: rain, freezing rain, sleet and snow.

Icing PIREPS: Several reports of light to moderate, clear and mixed icing from the surface to 6000 ft were received from 1300-2100L. Moderate to severe clear icing was also reported occasionally in the 2000-4000 ft layer.

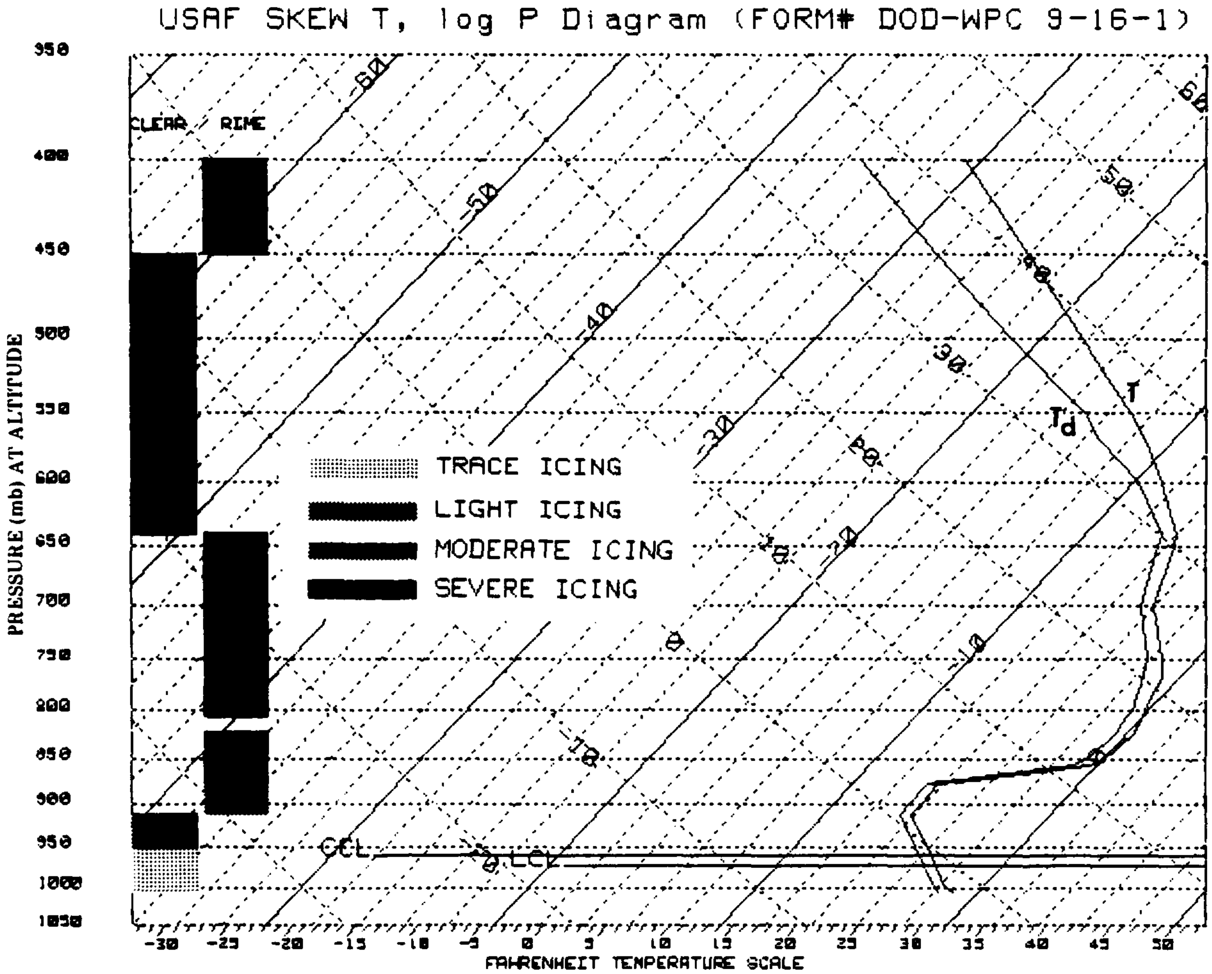

Fig. A-26. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Feb. 17, 1982 at 2300 GMT (1800 EST).

11. March 7, 1982

Surface Analysis (1200z, 0700L): Deepening low pressure center over Georgia coupled by low pressure trough over the Washington, DC area to a weak low center over New York caused widespread rain, snow and fog until about 2130L.

Conditions at DCA, BWI, and IAD:

Ceiling: around 500 ft, often obscured.

Surface temperature: near $0^{\circ}C$.

Winds: light, northeasterly.

Precipitation: steady light rain with freezing rain in the northern suburbs.

Icing PIREPS: None reported.

Surface Analysis (2300z, 1900L): Pressure rising rapidly after 2130L with a corresponding improvement in the weather.

Conditions at DCA, BWI, and IAD:

Ceiling: around 500 ft until 2130L, rising after that.

Surface temperature: warming slightly during the day to about $+2^{\circ}C$.

Winds: changing from northeasterly in the morning to northwesterly in the afternoon and evening.

Precipitation: steady light rain, freezing rain or snow until 2130L.

Icing PIREPS: None reported.

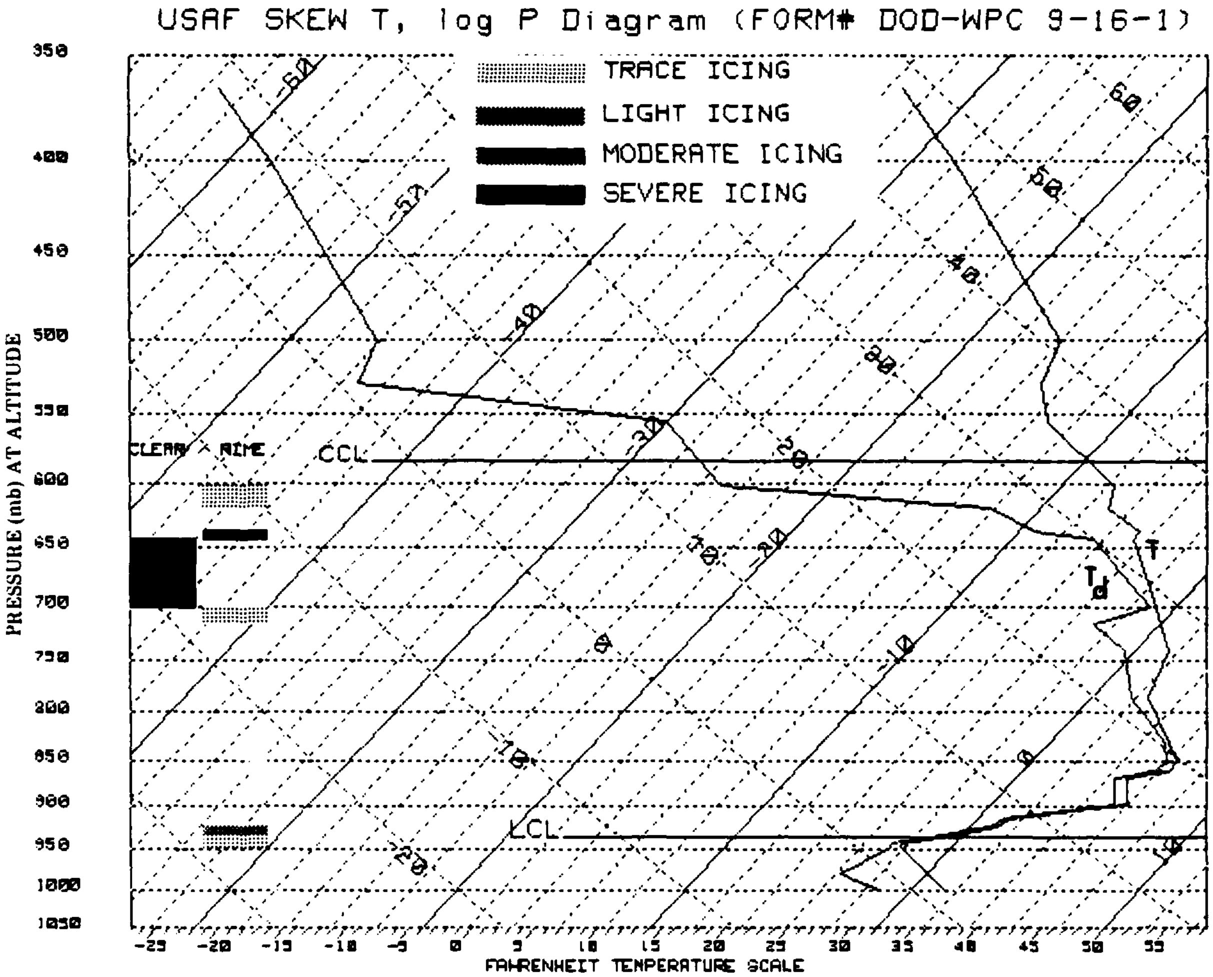

Fig. A-27. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Mar. 6, 1982 at 2300 GMT (1800 EST).

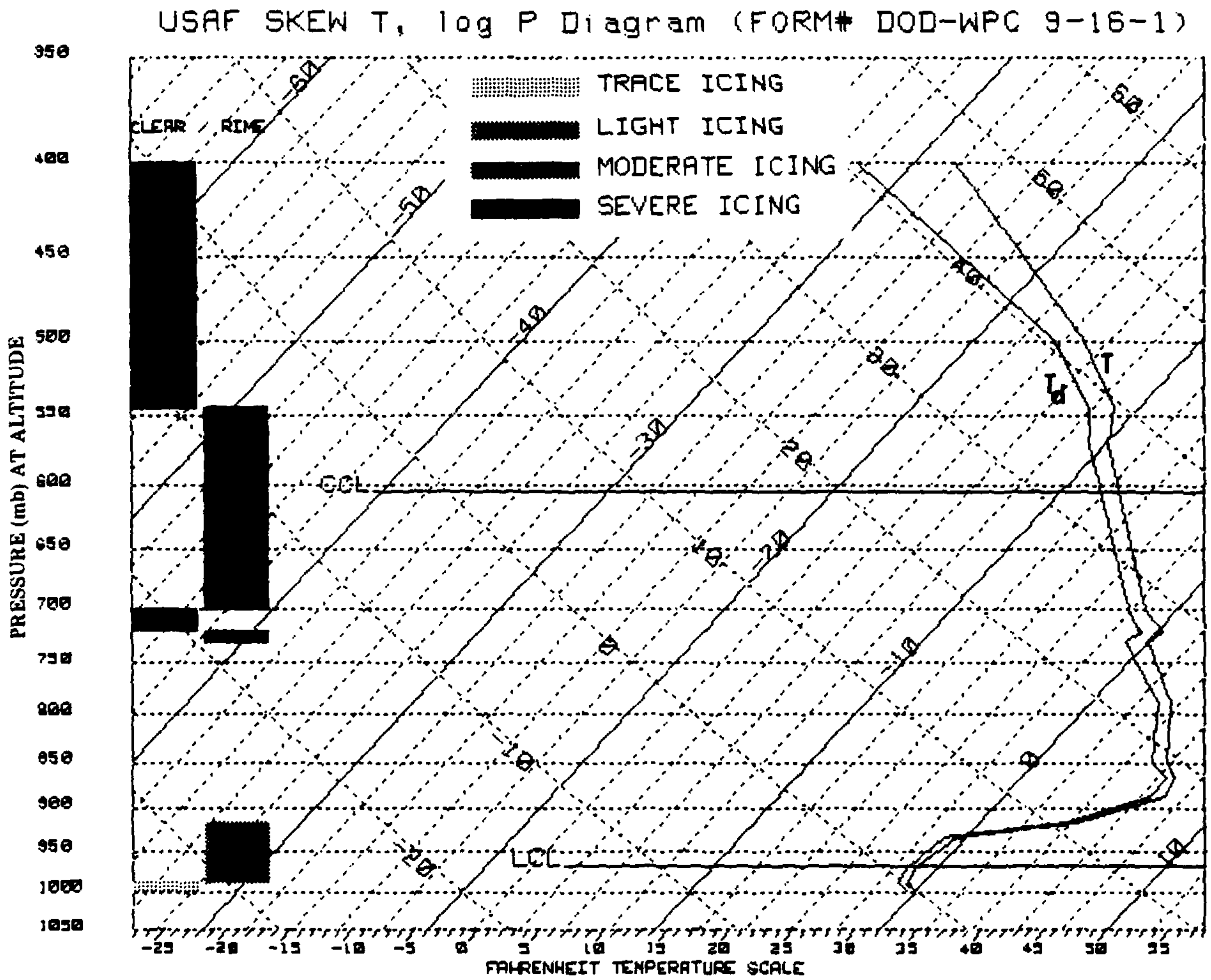

Fig. A-28. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Mar. 7, 1982 at 1100 GMT (0600 EST).

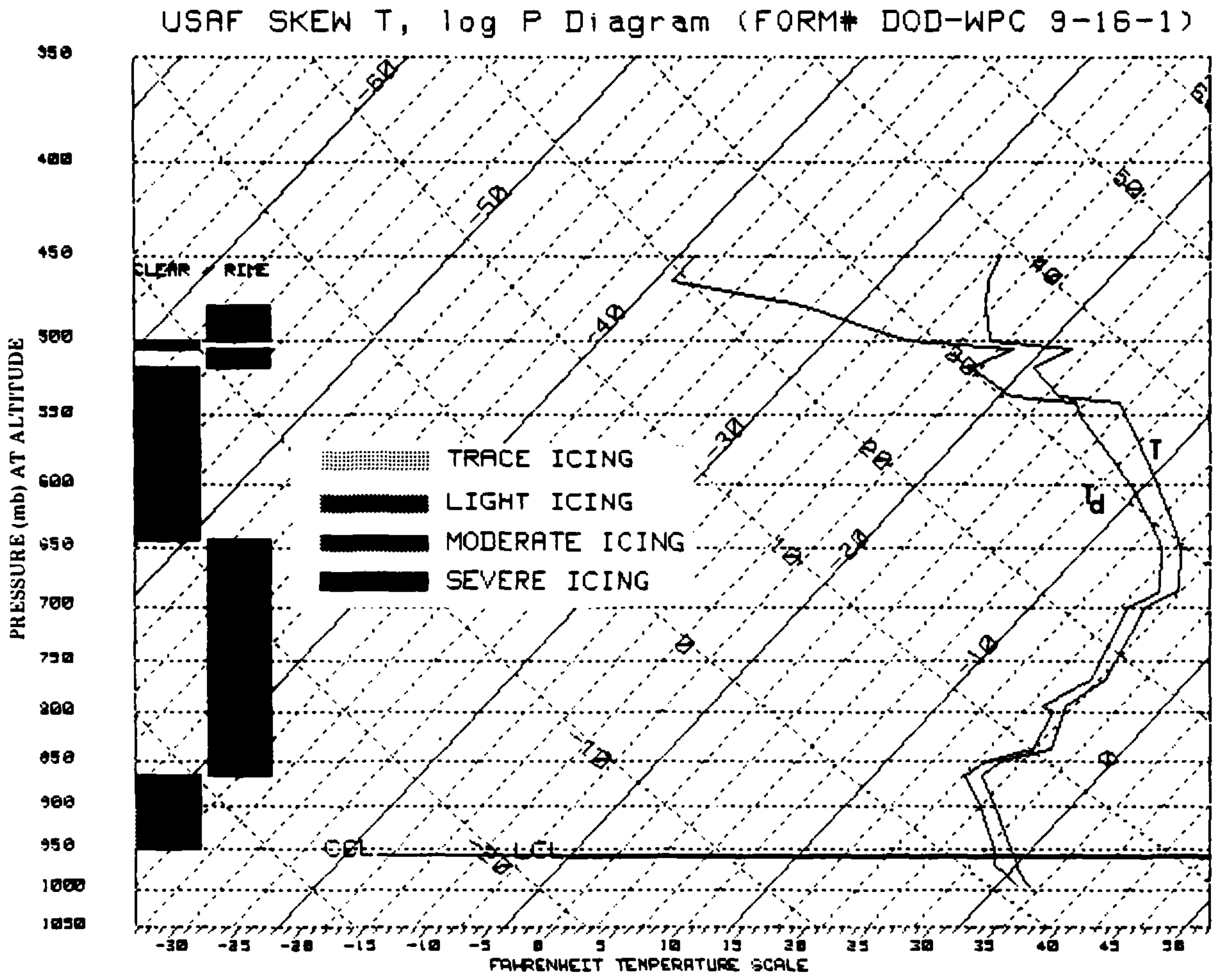

Fig. A-29. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Mar. 7, 1982 at 2300 GMT (1800 EST).

12. April 9, 1982

Surface Analysis (1200z, 0700L):

Conditions at DCA:

Ceiling: broken at 1000 ft with solid overcast somewhat higher. Ceiling much lower (500 ft) in northern suburbs.

Surface temperature: about +4°C at DCA lowering to 0°C in northern suburbs.

Winds: light or calm.

Precipitation: moderate snowfall in northern suburbs, becoming light, steady drizzle at DCA.

Conditions at IAD:

Ceiling: between 200 and 500 ft.

Surface temperature: +1°C.

Winds: light from the southeast.

Precipitation: moderate snowfall (estimated accumulation of 2.5 inches).

FRIDAY, APRIL 9, 1982

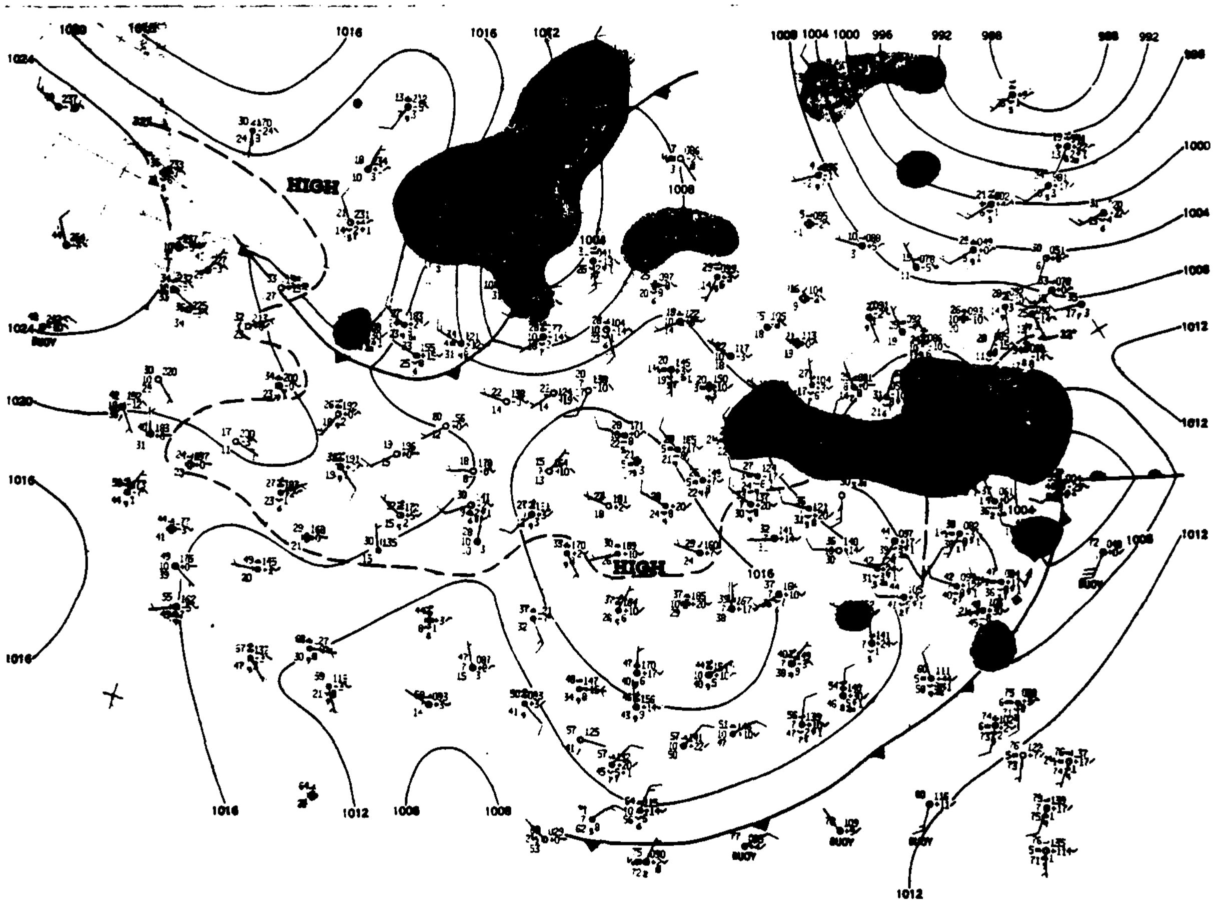

Fig. A-30. Surface weather for Apr. 9, 1982 at 1200 GMT (0700 EST).

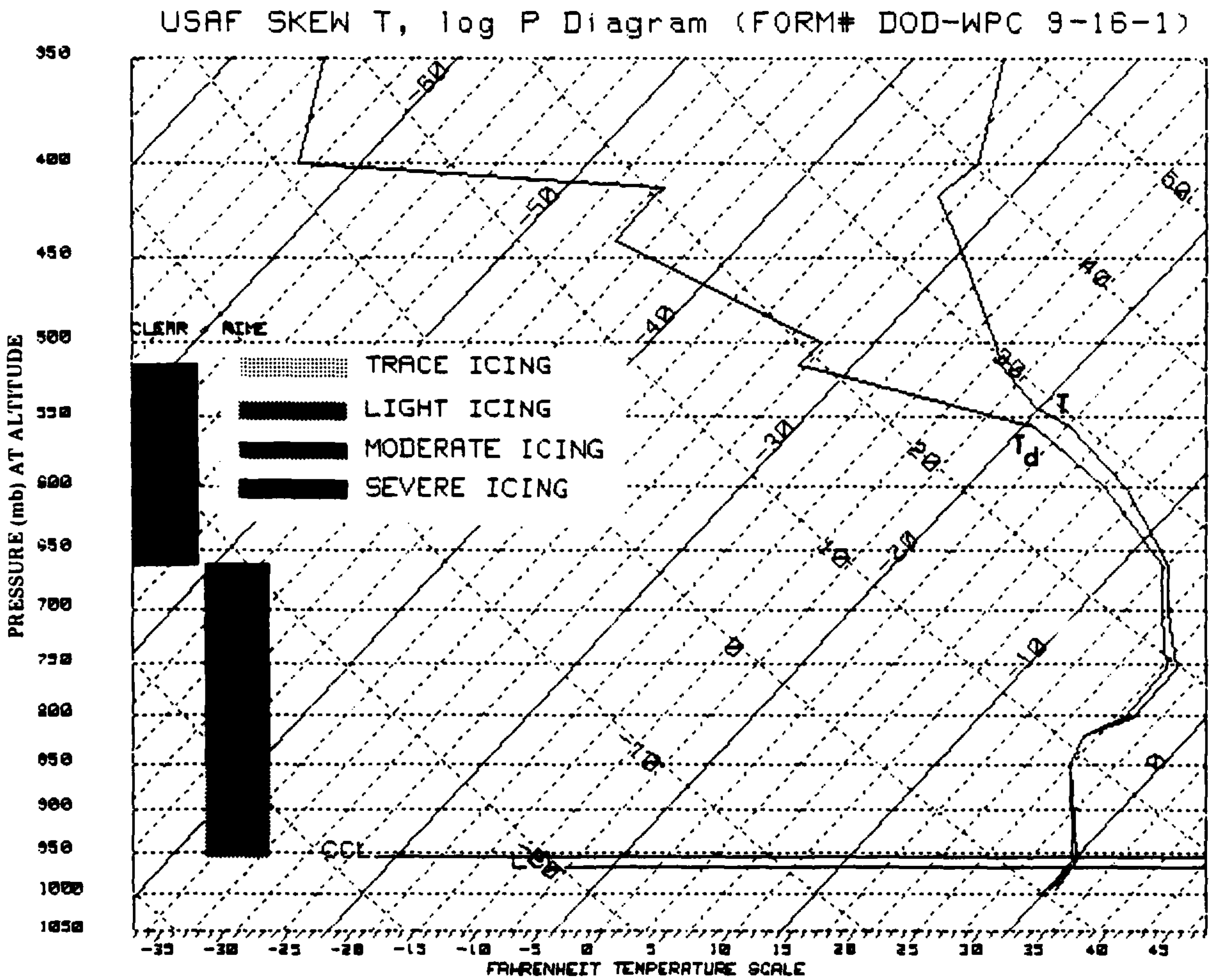

Fig. A-31. Air temperature, dewpoint temperature, and predicted aircraft icing severity above low ceiling conditions near Washington, DC, on Apr. 9, 1982 at 1100 GMT (0700 EST).

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